

An Investigation into the Structure of the Lumbo-sacral-coccygeal Cord of the Macaque Monkey (Macacus sinicus).

By MABEL PUREFOY FITZGERALD.

(Communicated by Professor Francis Gotch, M.A., D.Sc., F.R.S. Received June 17,—Read December 14, 1905.)

The following measurements of the cross-sections of the lumbo-sacral-coccygeal cord of the Macaque monkey (*Macacus sinicus*), with the calculations made therefrom, are here given as the preliminary results of a research made upon the spinal cord of this monkey.

For the purpose of presenting the facts as clearly as possible, the paper is illustrated by a series of curves based upon the above-mentioned records.

The method of using curves to represent the areas of the grey and white substance at different levels of the cord has been adopted by former investigators, namely, by Woroschiloff,* Lüderitz,† Krause and Aguerre,‡ and more recently by Donaldson and Davis§ in their paper published whilst this work was in the process of completion. The above-mentioned curves were constructed from measurements of the human spinal cord; the curves of Woroschiloff, Donaldson and Davis, and in part those of Lüderitz, being based upon the measurements published by Stilling|| in his classical work on the structure of the spinal cord.

It was intended to include a comparison of the human spinal cord with that of the monkey in this paper, but it is now thought advisable to publish the results of these investigations separately. The work done in this direction was also based upon Stilling's¶ measurements of human spinal cords.

Before entering into the details of the monkey's spinal cord, the methods employed in the research are here described as briefly as possible.

* Woroschiloff, "Der Verlauf der Motorischen und Sensiblen Bahnen durch das Lendenmark des Kaninchens," 'Berichte über die Verhandlungen der Königlich Sächsischen Gesellschaft der Wissenschaften zu Leipzig,' vol. 26, 1874.

† Lüderitz, C., "Über das Rückenmarksegment. Ein Beitrag zur Morphologie und Histologie des Rückenmarks," 'Archiv f. Anatomie u. Entwicklungsgeschichte,' Anat. Abtheil., 1881, pp. 423—495.

‡ Krause, R., and Aguerre, J., "Untersuchungen über den Bau des menschlichen Rückenmarkes mit besonderer Berücksichtigung der Neuroglia," 'Anatomischer Anzeiger,' vol. 18, 1900.

§ Donaldson, H. H., and Davis, D. J., "A Description of Charts showing the Areas of the Cross-sections of the Human Spinal Cord at the Level of each Spinal Nerve," 'The Journal of Comparative Neurology,' vol. 13, No. 1, 1903.

|| Stilling, B., 'Neue Untersuchungen über den Bau des Rückenmarkes,' Cassel, 1859.

¶ Stilling, B., *ibid.*

Technique.—The monkey was injected by Mann's* method, with picro-corrosive formaldehyde solution :—†

Formula.

Boiling water	100 c.c.
Sublimate	2·5 grammes.

When dissolved, add—

Picric acid	1 gramme.
-------------------	-----------

Allow to cool, and immediately before use add—

Formol	10 c.c.
--------------	---------

The spinal cord was allowed to remain in the vertebral canal until the following day, when it was removed with the spinal ganglia, and placed in 50 per cent. alcohol. The cord was then cut at different levels, and the various portions of it were dehydrated through gradual transference to alcohols of increasing strength, cleared in xylol, and embedded in paraffin (melting point, 52°). The cord was found to be well fixed throughout its length.

The lumbo-sacral-coccygeal cord was cut in serial sections, 10 μ and 20 μ thick, with the large Cambridge rocking microtome, which cuts flat sections, and the sections mounted on albuminised slides.‡ A certain number of serial sections were also cut at each of the levels of the dorsal (thoracic) and cervical cord, and similarly mounted.

After the removal of the paraffin by xylol, the sections were treated with absolute alcohol and then with iodine potassium iodide solution to remove the excess of corrosive sublimate and to decompose the albuminates of mercury. The iodine solution was removed with methylated spirit and distilled water. The sections were stained with eosin and toluidin blue§ (eosin, 10 minutes; toluidin blue, 2½ minutes; or for a longer time in similar proportions), and mounted in xylol balsam.

Three drawings were made at the level of each pair of spinal nerves, the sections being selected from the upper, middle, and lower portion of the line of entrance of the dorsal nerve root. The drawings were made with an Abbé Camera Lucida (Zeiss), a Zeiss microscope with the tube at 158, a No. 4 compensating ocular, and a Wray 3-inch lens. The magnification was equal to 20 diameters, except in dealing with certain sections in the lower regions of the cord, when it became advisable to use a magnification equal to 40 diameters. For this purpose a Leitz No. 1 lens was employed. The drawing paper was placed on a Bernhard drawing board (Zeiss), the board being level.

* Mann, G., 'Zeit. f. Wiss. Mikr.,' vol. 11, p. 482 (1894).

† Mann, G., 'Methods and Theory of Physiological Histology,' 1902, p. 97.

‡ Mann, G., 'Zeit. f. Wiss. Mikr.,' vol. 11, 1895, pp. 479—494.

§ Mann, G., *ibid.*

For taking the measurements of the drawings Amsler's planimeter No. 3 was used, so adjusted that one division on the disc indicated 100 sq. cm., and in those cases where the areas to be measured were very small the planimeter was set so that one division on the disc indicated 20 sq. cm. Every care was taken to obtain accuracy. In the majority of cases the pointer was carried five times round the area to be measured, and ten or more times when the areas were small. To guard against accidental errors the planimeter reading was always taken after completing the first circuit, and the result compared with that obtained by dividing the final reading by the number of times the pointer had been carried round. The difference was in all cases within the limits of instrumental error.

In each case the total area of the cross-sections of the cord was first determined. The sectional areas of the dorsal columns, the ventro-lateral columns, and the grey substance were then each measured separately in each half of the cord, the sum of the two halves being taken as the measurement of the whole.

The total area of the central canal was measured independently of the grey substance, and the results are given in Tables II, VI. These measurements are not separately represented in the charts, though it is necessary to take them into account in explaining the form of some of the curves.

The difference between the sum total of the measurements of the component parts of the cord and of the total section area was, in each case, noted as "error." As a rule the error was negative, its average value being 0.2 per cent. This may be regarded as due to "personal equation."

The total sectional area of the white substance was obtained by adding together the figures obtained for the dorsal and the ventro-lateral columns.

It must be here stated that the term "ventro-lateral" columns is used in this paper to signify the whole of the white substance ventral to Lissauer's "marginal zone." Lissauer* regarded this zone (Waldeyer's "Markbrücke") as belonging to the dorsal horn and forming a bridge between the dorsal and lateral strands of the white substance. It has therefore been used as a boundary between the two portions of the white substance, and has been measured with, and as a part of, the grey substance.

For measuring the grey substance in each half of the cord, the division was made by continuing a line from the dorsal median septum to the dorsal boundary of the central canal, and from the ventral boundary of this to the ventral median fissure. The grey substance was subsequently subdivided for the purpose of obtaining information as to the relative development of the "dorsal" and of the "ventral" horns. Since no actual boundary exists

* Lissauer, 'Archiv f. Psychiatrie u. Nervenkrankheiten,' vol. 17, 1886.

between the dorsal and the ventral portions of the grey substance, an arbitrary division was made as follows: In each half of the cord a line was drawn from the middle of the central canal to that point where the white substance projects furthest into the grey substance (see fig. 1). The grey substance dorsal to this was designated "dorsal horns," and that ventral to it the "ventral horns." From the seventh lumbar region (middle portion) downwards, a modification of this method was rendered necessary by the presence of the fibres of the *formatio reticularis*. The lines were therefore drawn from the central canal, in the manner already described, to the corresponding points which were still discernible, and then continued in a horizontal direction through the fibres of the *formatio reticularis* (see fig. 2).

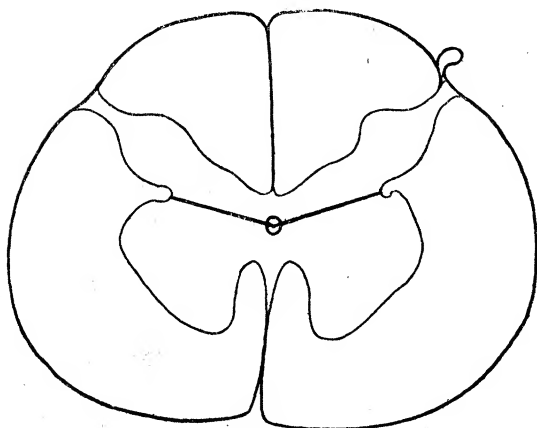


FIG. 1.

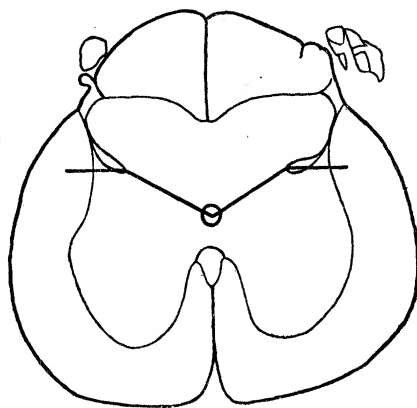


FIG. 2.

The "ventral horns" were measured in each case and the section area of the "dorsal horns" determined by subtracting the figures obtained for the "ventral horns" from the sum of the total grey substance. The "dorsal horns" therefore include Lissauer's "marginal zone," the substantia spongiosa and the substantia gelatinosa Rolandi.

Owing to the lack of sufficient differentiation, it was not possible to make an additional measurement of the substantia gelatinosa Rolandi. In a "control" monkey, fixed with picro-corrosive formaldehyde solution containing 20 c.c. instead of 10 c.c. formol for 100 c.c. of picro-corrosive solution, it appears to be possible to do this, but the work has not been carried out as yet.

Each table of figures is accompanied by a chart with curves, representing the same graphically.

In drawing the curves the same type of line and the same lettering have, as far as possible, been used throughout the series to denote the same constituent of the cord. The curves are to be read from left to right.

The number of nerve roots in the spinal cord of the Macaque monkey is as follows: 7 cervical, 12 dorsal, 7 lumbar, 4 sacral and 3 coccygeal.

The portion of the cord from which each pair of nerves arise has been spoken of throughout this paper as the corresponding "region."

The particular portion of the cord examined extended from the upper limit of the region of the first lumbar nerve to the lower limit of the third coccygeal region and measured approximately 6·3 cm.

In the charts dealing with section areas and with percentages (Charts I to IV and XIII, XIV), the length of the cord is expressed along the abscissa line in centimetres and parts of a centimetre. The uppermost section of the first lumbar region is taken as zero. The distance from zero to each measured section is given in centimetres or parts of a centimetre in a separate column in each table of figures (except in those where only mean results are quoted), and on the curves the observation points are marked by a dot or cross as nearly as possible in the exact position indicated in the table.

As a matter of convenience, the first drawing made in the first lumbar region was of a section occurring at 0·142 cm. below that taken as zero.

In the section area and percentage charts which give the complete results obtained (Charts I to IV and XIII, XIV), the numbers I, II, III, IV, etc., mark on the zero abscissa line the approximate cephalic end of the region of each pair of spinal nerves.

In the charts where the curves are constructed from mean figures (Charts V to XII, and XV to XX), the length of the cord and of the individual nerve regions has been disregarded, and the calculations referring to the region of each nerve (marked I, II, III, etc.) are plotted at equal distances along the abscissa.

The paper is arranged in the following order:—

- A 1. Areas of the cross-sections of the spinal cord and of the grey and of the white substance in the region of each spinal nerve.
- 2. Percentage of the grey and of the white substance in the cross-section of the cord.
- 3. Ratio of the total white substance, and of the dorsal and of the ventro-lateral white columns, to the grey substance.
- 4. Ratio of the dorsal and of the ventro-lateral white columns to the total white substance.
- 5. Ratio of the ventro-lateral to the dorsal columns.
- B 1. Section areas of the dorsal and of the ventral horns of the grey substance.
- 2. Percentage of the dorsal and of the ventral horns in the total grey substance.

3. Ratio of the ventral to the dorsal horns.
4. Ratio of the dorsal and of the ventral horns to the total area of the cross-section of the cord.
5. Ratio of the dorsal and of the ventro-lateral columns to the dorsal horns.
6. Ratio of the dorsal and of the ventro-lateral columns to the ventral horns.
7. Relative increase and decrease in the sectional area of the cord and of each of its component parts.

C 1. Diagrams. General configuration of the lumbo-sacral and coccygeal cord in sectional area.

2. Outline drawings of the cross-sections of the cord in the region of each spinal nerve.

A1.—Areas of the Cross-sections of the Spinal Cord and of the Grey and of the White Substance in the Region of each Spinal Nerve.

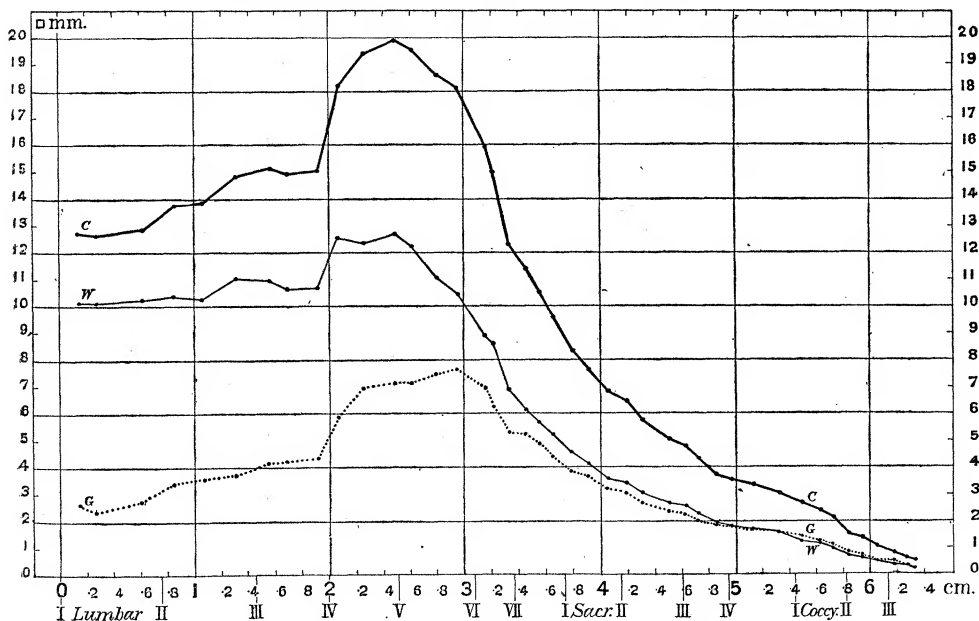


CHART I.—Curves showing the Areas of the Cross-sections of the Spinal Cord and of the Grey and of the White Substance (Tables I, II, III).

The ordinates denote section area in square millimetres, the abscissæ the length of the cord in centimetres measured from the uppermost section in the first lumbar region. The numbers (I, II, III, etc.) mark on abscissa line the approximate cephalic end of the region of each pair of spinal nerves.

Total area of the cross-section of the cord..... C, thick continuous line.
 Section area of the grey substance G, dotted line.
 Section area of the white substance W, thin continuous line.

(a) *Areas of the Cross-sections of the Spinal Cord.* (C.)

Table I.—Areas of the Cross-sections of the Cord (Charts I and II).

Region of cord.	Distance in cm. from uppermost section of I Lumbar region.	Planimeter measurement in sq. cm.	Actual area as calculated in sq. mm.	Mean.
Dorsal (thoracic)—				
VI.....	—	39·04	9·76	
XII.....	—	45·82	11·46	
Lumbar—				
I { Upper	0·142	50·94	12·74	12·76
I { Middle	0·268	50·64	12·66	
I { Lower	0·608	51·58	12·90	
II { Upper	0·846	55·22	13·81	14·17
II { Middle	1·058	55·46	13·87	
II { Lower	1·302	59·40	14·85	
III { Upper	1·558	60·42	15·11	15·03
III { Middle	1·681	59·66	14·92	
III { Lower	1·918	60·30	15·08	
IV { Upper	2·064	72·86	18·22	19·16
IV { Middle	2·244	77·58	19·40	
IV { Lower	2·484	79·50	19·88	
V { Upper	2·608	78·00	19·50	18·75
V { Middle	2·794	74·40	18·60	
V { Lower	2·944	72·60	18·15	
VI { Upper	3·154	63·64	15·91	14·42
VI { Middle	3·205	60·06	15·02	
VI { Lower	3·328	49·32	12·33	
VII { Upper	3·450	45·66	11·42	10·54
VII { Middle	3·557	42·32	10·58	
VII { Lower	3·642	38·48	9·620	
Sacral—				
I { Upper	3·782	33·50	8·375	7·693
I { Middle	3·906	31·44	7·860	
I { Lower	4·057	27·38	6·845	
II { Upper	4·197	25·86	6·465	5·758
II { Middle	4·316	23·14	6·785	
II { Lower	4·509	20·10	5·025	
III { Upper	4·623	19·20	4·800	4·310
III { Middle	4·723	17·44	4·360	
III { Lower	4·858	15·08	3·770	
IV { Upper	4·974	14·20	3·550	3·325
IV { Middle	5·138	13·40	3·350	
IV { Lower	5·312	12·30	3·075	
Coccygeal—				
I { Upper	5·486	10·76	2·690	2·403
I { Middle	5·622	9·56	2·390	
I { Lower	5·726	8·52	2·130	
II { Upper	5·847	24·08	1·505	1·319
II { Middle	5·939	22·18	1·386	
II { Lower	6·058	17·04	1·065	
III { Upper	6·174	3·34	0·8350	0·6679
III { Middle	6·278	10·34	0·6462	
III { Lower	6·331	2·09	0·5225	

The section area of the spinal cord (C) (Charts I, II, Table I) increases from the region of the first lumbar to the lower portion of that of the fourth lumbar nerve, where the maximum size of the lumbar enlargement is reached (19·88 sq. mm.).

By comparing the measurements of the first lumbar region with the measurements of the twelfth dorsal (thoracic) given in the accompanying table, it will be seen, that the increase in the section area of the cord has begun prior to the region of the first lumbar nerve.

The increase is gradual to the lower portion of the third lumbar region. It becomes very marked in the fourth, for when the maximum is reached the section area of the cord is more than one and a-half times as great as in the first lumbar region. The section area remains very much the same (19.5 sq. mm.) from the middle portion of the fourth to the upper portion of the fifth lumbar region. The gradual decrease in section area in the remaining portions of the fifth is followed by a marked diminution in the sixth lumbar region. The section area in the lower portion of the sixth (12.33 sq. mm.) is rather less than that in the first lumbar region. Continuing with rapidity through the regions of the seventh lumbar and the first sacral nerves, the decrease becomes more and more gradual as the lower regions of the cord are reached. The section area in the lower portion of the third coccygeal region is about 1/40th that in the fourth lumbar region (*i.e.*, 0.5—19.88 sq. mm.).

The section area of the grey substance (G) (Charts I, II, Table II) increases from the region of the first to that of the fifth lumbar nerve, and is the potent factor in the enlargement of the total section area of the cord.

The maximum (7.65 sq. mm.) is reached in the lower portion of the fifth lumbar region and it is noteworthy that this is found at a lower level than the maximum section areas of the cord and of the white substance.

The grey substance decreases in section area from the fifth lumbar region to the end of the cord.

The increase in section area, though continuous, is gradual from the first to the third lumbar region (lower part), becomes rapid in the fourth, and is again gradual in the fifth lumbar region. In the middle portion of the fourth and the upper portion of the sixth lumbar region the section area is the same (*ca.* 7 sq. mm.).

The decrease is rapid from the fifth to the lower portion of the region of the sixth lumbar nerve, after which the reduction of section area takes place very gradually.

In the fifth lumbar region (maximum) the section area is about three times as great as that in the first lumbar region (upper part) (*ca.* 7.6 to 2.6 sq. mm.); in the second sacral it is much the same as in the first lumbar, and in the third coccygeal region is about 1/30th that in the fifth lumbar.

(b) *Section Area of the Grey Substance.* (G.)

Table II.—Section Area of the Grey Substance and of the Central Canal (Charts I, II, V, XIII).

Region of cord.	Distance in cm. from the uppermost section of I Lumbar region.	Grey substance.		Mean.	Central canal.	
		Planimeter measurement in sq. cm.	Actual area as calculated in sq. mm.		Planimeter measurement in sq. cm.	Actual area as calculated in sq. mm.
Dorsal(thoracic)—						
VI	—	4·98	1·245	—	0·02	0·0050
XII	—	7·56	1·890	—	0·04	0·0100
Lumbar—						
I { Upper ...	0·142	10·22	2·555	2·607	0·08	0·0200
I { Middle ...	0·268	9·94	2·485		0·06	0·0150
I { Lower ...	0·608	11·12	2·780		0·06	0·0150
II { Upper ...	0·846	13·58	3·395	3·553	0·03	0·0075
II { Middle ...	1·058	14·20	3·550		0·04	0·0100
II { Lower ...	1·302	14·86	3·715		0·11	0·0275
III { Upper ...	1·558	16·64	4·160	4·240	0·14	0·0350
III { Middle ...	1·681	16·90	4·225		0·08	0·0200
III { Lower ...	1·918	17·34	4·335		0·08	0·0200
IV { Upper ...	2·064	23·42	5·855	6·651	0·08	0·0200
IV { Middle ...	2·244	27·86	6·965		0·08	0·0200
IV { Lower ...	2·484	28·53	7·133		0·16	0·0400
V { Upper ...	2·608	28·60	7·150	7·410	0·14	0·0350
V { Middle ...	2·794	29·74	7·435		0·18	0·0450
V { Lower ...	2·944	30·58	7·645		0·18	0·0450
VI { Upper ...	3·154	27·90	6·975	6·234	0·12	0·0300
VI { Middle ...	3·205	25·49	6·373		0·12	0·0200
VI { Lower ...	3·328	21·42	5·355		0·14	0·0350
VII { Upper ...	3·450	20·84	5·210	4·809	0·08	0·0200
VII { Middle ...	3·557	19·45	4·863		0·09	0·0225
VII { Lower ...	3·642	17·42	4·355		0·12	0·0300
Sacral—						
I { Upper ...	3·782	15·28	3·820	3·573	0·08	0·0200
I { Middle ...	3·906	14·74	3·685		0·04	0·0100
I { Lower ...	4·057	12·86	3·215		0·04	0·0100
II { Upper ...	4·197	12·14	3·035	2·697	0·03	0·0075
II { Middle ...	4·316	10·74	2·685		0·03	0·0075
II { Lower ...	4·509	9·48	2·370		0·03	0·0075
III { Upper ...	4·623	8·90	2·225	2·050	0·04	0·0100
III { Middle ...	4·723	8·34	2·085		0·02	0·0050
III { Lower ...	4·858	7·36	1·840		0·04	0·0100
IV { Upper ...	4·974	6·98	1·745	1·642	0·03	0·0075
IV { Middle ...	5·138	6·66	1·665		0·03	0·0075
IV { Lower ...	5·312	6·06	1·515		0·03	0·0075
Coccygeal—						
I { Upper ...	5·486	5·66	1·415	1·267	0·03	0·0075
I { Middle ...	5·622	5·06	1·265		0·03	0·0075
I { Lower ...	5·726	4·48	1·120		0·03	0·0075
II { Upper ...	5·847	12·34	0·7712	0·6797	0·08	0·0050
II { Middle ...	5·939	11·55	0·7218		0·08	0·0050
II { Lower ...	6·058	8·74	0·5462		0·10	0·0062
III { Upper ...	6·174	1·70	0·4250	0·3266	0·03	0·0075
III { Middle ...	6·278	4·92	0·3075		0·07	0·0043
III { Lower ...	6·331	0·99	0·2475		0·02	0·0050

(c) *Section Area of the White Substance. (W.)*

Table III.—Section Area of the White Substance (Charts I and VI).

Region of cord.	Distance in cm. from uppermost section of I Lumbar region.	Planimeter measurement in sq. cm.	Actual area as calculated in sq. mm.	Mean.
Dorsal (thoracic)—				
VI.....	—	33.88	8.470	
XII.....	—	38.24	9.560	
Lumbar—				
I { Upper	0.142	40.52	10.13	10.12
I { Middle	0.268	40.64	10.16	
I { Lower	0.608	40.26	10.07	
II { Upper	0.846	41.54	10.39	10.58
II { Middle	1.058	41.18	10.30	
II { Lower	1.302	44.26	11.07	
III { Upper	1.558	43.62	10.91	10.76
III { Middle	1.681	42.68	10.67	
III { Lower	1.918	42.80	10.70	
IV { Upper	2.064	49.30	12.33	12.46
IV { Middle	2.244	49.54	12.39	
IV { Lower	2.484	50.70	12.68	
V { Upper	2.608	49.06	12.27	11.27
V { Middle	2.794	44.32	11.08	
V { Lower	2.944	41.90	10.48	
VI { Upper	3.154	35.62	8.905	8.153
VI { Middle	3.205	34.49	8.623	
VI { Lower	3.328	27.72	6.930	
VII { Upper	3.450	24.60	6.150	5.682
VII { Middle	3.557	22.68	5.670	
VII { Lower	3.642	20.90	5.225	
Sacral—				
I { Upper	3.782	18.12	4.530	4.097
I { Middle	3.906	16.66	4.165	
I { Lower	4.057	14.38	3.595	
II { Upper	4.197	13.64	3.410	3.047
II { Middle	4.316	12.32	3.080	
II { Lower	4.509	10.60	2.650	
III { Upper	4.623	10.24	2.560	2.250
III { Middle	4.723	9.10	2.275	
III { Lower	4.858	7.66	2.915	
IV { Upper	4.974	7.14	1.785	1.667
IV { Middle	5.138	6.68	1.670	
IV { Lower	5.312	6.18	1.545	
Coccygeal—				
I { Upper	5.486	5.02	1.255	1.123
I { Middle	5.622	4.48	1.120	
I { Lower	5.726	3.98	0.9950	
II { Upper	5.847	11.72	0.7325	0.6345
II { Middle	5.939	10.58	0.6612	
II { Lower	6.058	8.16	0.5099	
III { Upper	6.174	1.59	0.3975	0.3345
III { Middle	6.278	5.38	0.3362	
III { Lower	6.331	1.08	0.2700	

The section area of the white substance (W) (Chart I, Table III) increases from the region of the first lumbar to that of the fourth lumbar nerve, and

decreases from the latter region to the end of the cord. The increase in the white substance (W) is not so great as that of the grey substance (G).

There is very little alteration in the section area of the white substance through the first and the greater part of the second lumbar regions, but a marked increase takes place between the lower portion of the third and the fourth and in the fourth lumbar region. The chief development of the white substance extends through the fourth and the upper portion of the fifth lumbar region. The maximum (12·68 sq. mm.) being reached in the lower portion of the fourth, is thus found in the same region as the maximum section area of the cord.

The decrease is rapid in the greater part of the fifth lumbar, the section area of the white substance in the lower part of this region (10·48 sq. mm.) being about the same as that in the first lumbar.

Attention must be drawn to the fact that whilst this marked decrease is taking place in the section area of both the white substance and of the cord in the fifth lumbar region, the section area of the grey substance is still increasing.

The rapid diminution of the section area of the white substance continues to the seventh lumbar region; after this the decrease is gradual.

From the seventh lumbar to the third sacral region (lower) the section area of the white substance (W) is only slightly greater than that of the grey substance (G), whilst from the fourth sacral region to the end of the cord the section areas of the two substances are almost the same.

In Chart I, and in the above description, the white substance (W) has been regarded as a whole. Through the remainder of the paper it is also dealt with in two distinct parts—*i.e.*, dorsal columns and ventro-lateral columns. The latter term is here used, as before stated (p. 90), to signify the whole of the white substance other than the dorsal columns. By this means it is possible to obtain information as to the relative value of the contributions made to the white substance of the cord by dorsal roots and by central grey substances respectively.*

The section areas of the dorsal columns and of the ventro-lateral columns are shown in the following chart (II):—

* It must be remembered that, owing to the presence of some endogenous fibres amongst those of extra-spinal origin in the dorsal columns, the comparison can only be regarded as of general value.

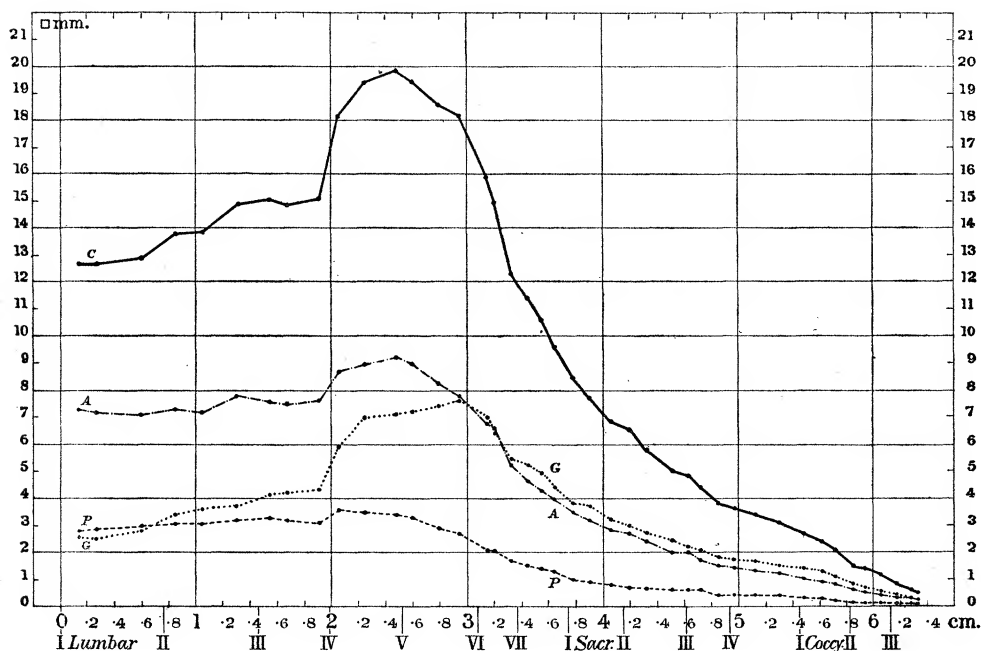


CHART II.—Curves showing the Areas of the Cross-sections of the Cord, of the Grey Substance, and of the Dorsal and the Ventro-lateral Columns of the White Substance (Tables I, II, IV, V).

The ordinates denote section area in square millimetres, the abscissæ the length of the cord in centimetres measured from the uppermost section in the first lumbar region. The numbers (I, II, III, etc.) mark approximately the cephalic end of the region of each pair of spinal nerves.

Total area of the cross-section of the cord	C, thick continuous line.
Section area of the grey substance	G, dotted line.
Section area of the dorsal white columns.....	P, broken line.
Section area of the ventro-lateral white columns ...	A, line and dot.

The section area of the dorsal columns (P) (Chart II, Table IV), is 2.81 sq. mm. in the upper portion of the first lumbar region, and increases gradually from this to the fourth lumbar, where it reaches its maximum, 3.6 sq. mm.

The maximum thus occurs in the region of the same lumbar nerve as the maximum section areas of the cord and of the white substance; but it differs in position to these, being found in the upper instead of the lower portion of the fourth lumbar region. It occurs at some distance, therefore, from the maximum section area of the grey substance (*v. L.*, lower).

The larger areas of the dorsal columns extend through the fourth and the upper portion of the fifth lumbar region. The section area in the middle portion of the latter region is much the same as that in the first lumbar.

(d) *Section Area of the Dorsal Columns.* (P.)

Table IV.—Section Area of the Dorsal Columns (Charts II and VII).

Region of cord.	Distance in cm. from uppermost section of I Lumbar region.	Planimeter measurement in sq. cm.	Actual area as calculated in sq. mm.	Mean.
Dorsal (thoracic)—				
VI.....	—	8·84	2·210	
XII.....	—	10·46	2·615	
Lumbar—				
I { Upper	0·142	11·24	2·810	2·895
{ Middle	0·268	11·68	2·920	
{ Lower	0·608	11·82	2·955	
II { Upper	0·846	12·52	3·130	3·138
{ Middle	1·058	12·22	3·055	
{ Lower	1·302	12·92	3·230	
III { Upper	1·558	13·18	3·295	3·195
{ Middle	1·681	12·72	3·180	
{ Lower	1·918	12·44	3·110	
IV { Upper	2·064	14·44	3·610	3·508
{ Middle	2·244	13·94	3·485	
{ Lower	2·484	13·72	3·430	
V { Upper	2·608	13·06	3·265	2·952
{ Middle	2·794	11·46	2·865	
{ Lower	2·944	10·90	2·725	
VI { Upper	3·154	8·56	2·140	1·960
{ Middle	3·205	8·28	2·070	
{ Lower	3·328	6·68	1·670	
VII { Upper	3·450	6·06	1·515	1·385
{ Middle	3·557	5·54	1·385	
{ Lower	3·642	5·02	1·255	
Sacral—				
I { Upper	3·782	4·08	1·020	0·9016
{ Middle	3·906	3·68	0·9200	
{ Lower	4·057	3·06	0·7650	
II { Upper	4·197	2·92	0·7300	0·6783
{ Middle	4·316	2·78	0·6950	
{ Lower	4·509	2·44	0·6100	
III { Upper	4·623	2·24	0·5600	0·5183
{ Middle	4·723	2·20	0·5500	
{ Lower	4·858	1·78	0·4450	
IV { Upper	4·974	1·64	0·4100	0·3866
{ Middle	5·138	1·54	0·3850	
{ Lower	5·312	1·46	0·3650	
Coccygeal—				
I { Upper	5·486	1·08	0·2700	0·2433
{ Middle	5·622	1·02	0·2550	
{ Lower	5·726	0·82	0·2050	
II { Upper	5·847	2·36	0·1475	0·1291
{ Middle	5·939	2·22	0·1387	
{ Lower	6·058	1·62	0·1012	
III { Upper	6·174	0·27	0·0675	0·0529
{ Middle	6·278	0·78	0·0487	
{ Lower	6·331	0·17	0·0425	

The decrease in the section area of the dorsal columns is much more rapid than the increase, and, beginning in the fourth lumbar region, is continuous

to the end of the cord. The decrease is most marked between the fifth lumbar and the first sacral regions, and becomes very gradual in the lower sacral and in the coccygeal regions.

In the first lumbar region the section area of the dorsal columns (P) is greater than that of the grey substance (G). This is also the case in both the sixth and twelfth dorsal (thoracic) regions (see Tables II and IV). In the second lumbar region, and throughout the remainder of the cord below this, the section area of the dorsal columns is less than that of the grey substance.

It is of interest to note that the section area of the dorsal columns in the greater part of the sixth lumbar region is approximately the same as that in the sixth dorsal (thoracic).

The section area of the ventro-lateral columns (A) (Chart II, Table V) remains about the same through the first and the greater part of the second lumbar region (*ca.* 7.2 sq. mm.). It is somewhat larger in the third, and increases rapidly from the lower portion of this and throughout the fourth lumbar region.

The maximum (9.25 sq. mm.) is reached in the lower portion of the fourth lumbar, and thus occurs in the same region as the maximum section areas of the cord, white substance, and dorsal columns.

The chief development of the ventro-lateral columns extends from the third lumbar (lower) to the lower portion of the fifth lumbar region, the section area in the upper portion of the fifth being nearly the same as that in the lower portion of the fourth.

The section area diminishes from the fourth lumbar region (lower part) to the end of the cord. The decrease is rapid to the third sacral region, and is most marked in the fifth, sixth, and seventh lumbar regions.

From the first to the fifth lumbar region inclusive, the section area of the ventro-lateral columns (A) exceeds that of the grey substance (G), especially in the first three lumbar regions. The section areas are approximately equal in the sixth lumbar region. From the seventh lumbar region to the end of the cord the section area of the ventro-lateral columns is less than that of the grey substance, but the areas approach each other very nearly in the lower coccygeal regions.

The increase in the section area of the whole white substance (Chart I, W) between the first and the fourth lumbar, and the decrease between the fourth and the sixth lumbar regions, is chiefly due to the variation in the ventro-lateral columns (Chart II, A). The actual increase and decrease in the section area of these columns (A) being about twice as great as that of the dorsal columns (P).

(e) *Section Area of the Ventro-lateral Columns.* (A).

Table V.—Section Area of the Ventro-lateral Columns (Charts II and VIII).

Region of cord.	Distance in cm. from uppermost section of I Lumbar region.	Planimeter measurement in sq. cm.	Actual area as calculated in sq. mm.	Mean.
Dorsal (thoracic)—				
VI.....	—	25·04	6·260	
XII.....	—	27·78	6·945	
Lumbar—				
I { Upper	0·142	29·28	7·320	7·223
I { Middle	0·268	28·96	7·240	
I { Lower	0·608	28·44	7·110	
II { Upper	0·846	29·02	7·255	7·443
II { Middle	1·058	28·96	7·240	
II { Lower	1·302	31·34	7·835	
III { Upper	1·558	30·44	7·610	7·563
III { Middle	1·681	29·96	7·490	
III { Lower	1·918	30·36	7·590	
IV { Upper	2·064	34·86	8·715	8·953
IV { Middle	2·244	35·60	8·900	
IV { Lower	2·484	36·98	9·245	
V { Upper	2·608	36·00	9·000	8·322
V { Middle	2·794	32·86	8·215	
V { Lower	2·944	31·00	7·750	
VI { Upper	3·154	27·06	6·765	6·193
VI { Middle	3·205	26·21	6·553	
VI { Lower	3·328	21·04	5·260	
VII { Upper	3·450	18·54	4·635	4·297
VII { Middle	3·557	17·14	4·285	
VII { Lower	3·642	15·88	3·970	
Sacral—				
I { Upper	3·782	14·04	3·510	3·195
I { Middle	3·906	12·98	3·240	
I { Lower	4·057	11·32	2·840	
II { Upper	4·197	10·72	2·680	2·368
II { Middle	4·316	9·54	2·385	
II { Lower	4·509	8·16	2·040	
III { Upper	4·623	8·00	2·000	1·732
III { Middle	4·723	6·90	1·725	
III { Lower	4·858	5·88	1·470	
IV { Upper	4·974	5·50	1·375	1·280
IV { Middle	5·138	5·14	1·285	
IV { Lower	5·312	4·72	1·180	
Coccygeal—				
I { Upper	5·486	3·94	0·9850	0·8800
I { Middle	5·622	3·46	0·8650	
I { Lower	5·726	3·16	0·7900	
II { Upper	5·847	9·36	0·5850	0·5051
II { Middle	5·939	8·36	0·5225	
II { Lower	6·058	6·54	0·4087	
III { Upper	6·174	1·32	0·3300	0·2816
III { Middle	6·278	4·60	0·2875	
III { Lower	6·331	0·91	0·2275	

A2. The Percentage of the Grey and of the White Substance in the Cross-section of the Cord.

Table VI.—Percentage of the Grey and of the White Substances and of the Central Canal in the Cross-sections of the Cord. The total area of each cross-section of the cord = 100 (Charts III, IV, V, and VI).

Region of cord.	Distance in cm. from uppermost section of I Lumbar region.	Percentage of grey substance.	Mean per- centage.	Percentage of white substance.	Mean per- centage.	Percentage of the central canal.
Dorsal (thoracic)—						
VI	—	12.76	—	86.78	—	0.051
XII	—	16.50	—	83.46	—	0.087
Lumbar—						
I { Upper ...	0.142	20.06	20.42	79.54	79.28	0.157
Middle ...	0.268	19.63		80.25		0.118
Lower ...	0.608	21.56		78.05		0.116
II { Upper ...	0.846	24.59	25.07	75.23	74.66	0.054
Middle ...	1.058	25.60		74.25		0.072
Lower ...	1.302	25.02		74.51		0.185
III { Upper ...	1.558	27.54	28.21	72.19	71.57	0.231
Middle ...	1.681	28.33		71.54		0.134
Lower ...	1.918	28.76		70.98		0.132
IV { Upper ...	2.064	32.14	34.65	67.66	65.10	0.109
Middle ...	2.244	35.91		63.86		0.103
Lower ...	2.484	35.89		63.77		0.201
V { Upper ...	2.608	36.67	39.59	62.90	60.06	0.179
Middle ...	2.794	39.97		59.57		0.241
Lower ...	2.944	42.12		57.71		0.247
VI { Upper ...	3.154	43.84	43.25	55.97	56.53	0.188
Middle ...	3.205	42.48		57.41		0.199
Lower ...	3.328	43.43		56.20		0.283
VII { Upper ...	3.450	45.64	45.62	53.88	53.93	0.175
Middle ...	3.557	45.96		53.59		0.212
Lower ...	3.642	45.27		54.31		0.311
Sacral—						
I { Upper ...	3.782	45.61	46.49	54.09	53.20	0.238
Middle ...	3.906	46.88		52.99		0.127
Lower ...	4.057	46.97		52.52		0.146
II { Upper ...	4.197	46.95	46.84	52.75	52.91	0.116
Middle ...	4.316	46.41		53.24		0.129
Lower ...	4.509	47.16		52.74		0.149
III { Upper ...	4.623	46.35	47.66	53.33	52.10	0.208
Middle ...	4.723	47.82		52.18		0.114
Lower ...	4.858	48.81		50.80		0.265
IV { Upper ...	4.974	49.15	49.37	50.28	50.12	0.211
Middle ...	5.138	49.70		49.85		0.223
Lower ...	5.312	49.27		50.24		0.243
Coccygeal—						
I { Upper ...	5.486	52.60	52.70	46.65	46.74	0.278
Middle ...	5.622	52.93		46.86		0.313
Lower ...	5.726	52.58		46.71		0.352
II { Upper ...	5.847	51.25	51.53	48.67	48.09	0.332
Middle ...	5.939	52.07		47.70		0.360
Lower ...	6.058	51.29		47.89		0.586
III { Upper ...	6.174	50.90	48.62	47.60	50.44	0.898
Middle ...	6.278	47.58		52.03		0.676
Lower ...	6.331	47.37		51.68		0.956

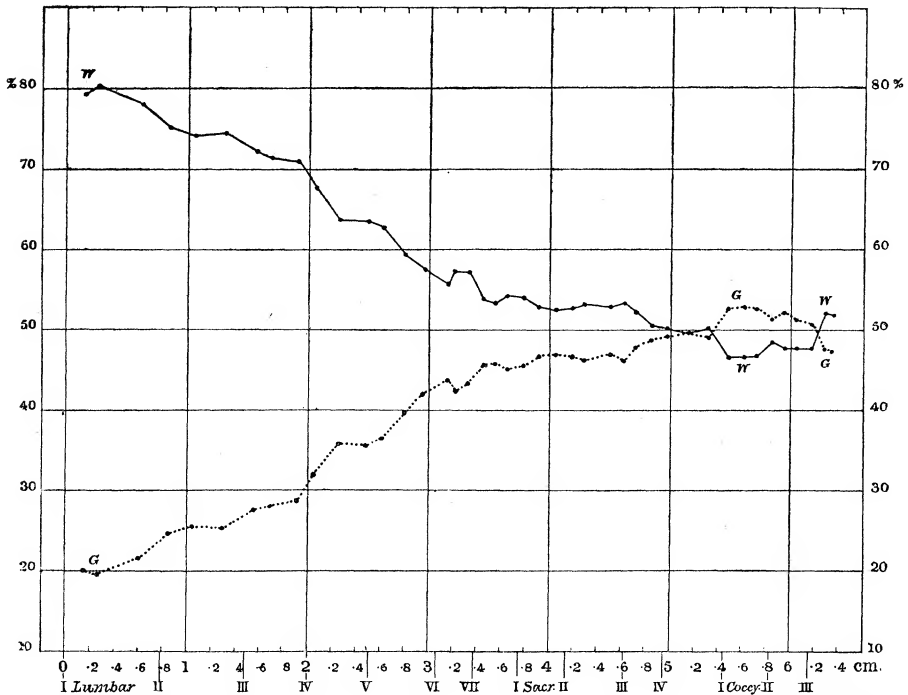


CHART III.—Curves showing the Percentage Value of the Grey and of the White Substance in the Cross-section of the Cord (Table VI).

The total area of each cross-section of the cord = 100. The ordinates denote percentage value, the abscissæ the length of the cord in centimetres measured from the uppermost section of the first lumbar region. The numbers (I, II, III, etc.) mark approximately the cephalic end of the region of each pair of spinal nerves.

Percentage of grey substance..... G, dotted line.

Percentage of white substance ... W, thin continuous line.

The percentage of grey substance in the cross-section of the cord (Chart III, G, Table VI) rises almost continuously from *ca.* 20 per cent. in the first lumbar region to 52 per cent. in the first coccygeal (maximum 52.9 per cent.). A slight fall in the percentage in the second coccygeal region is followed by a marked fall to 47 per cent. in the third coccygeal.

The percentage of white substance, on the other hand, falls almost continuously from *ca.* 80 per cent. in the first lumbar region to *ca.* 47 per cent. in the first coccygeal; and corresponding to the fall in percentage of grey substance, a slight rise in the second coccygeal is followed by a rapid rise to 51 per cent. in the third coccygeal region.

Thus, between the regions of the first lumbar and the first coccygeal nerve, there is an absolute rise in percentage of grey substance and a fall in that of white substance of 32.

The rise and fall in percentage of grey and white substance respectively is most rapid between the upper portion of the first lumbar region and the lower portion of the fifth lumbar region. Within these limits the rise and fall is most marked in the fourth and fifth lumbar regions, more particularly in the fifth. Through the first, second, and the greater part of the third sacral regions, there is very little variation in the percentage values.

In the middle portion of the fourth sacral region the percentage of grey and white substance is equal, and through the first, second, and part of the third coccygeal region the percentage of grey substance is higher than that of white.

The maximum percentage of grey substance and the lowest percentage of white substance is found in the first coccygeal region (*ca.* 53 per cent. and 47 per cent. respectively). The maximum percentage of white and the lowest percentage of grey substance is found in the first lumbar region (*ca.* 80 per cent. and 20 per cent. respectively).

(a) *Percentage of the Dorsal Columns (P) (Chart IV, Table VII).*

The percentage of the dorsal columns (P) to the cross-section of the cord falls from the first lumbar region to the end of the cord.

The dorsal columns constitute 22 per cent. of the cross-section of the cord in the first lumbar region, their percentage value being, approximately, the same in this as in both the sixth and twelfth dorsal (thoracic) regions (see Table VII).

Through the first lumbar region the percentage value of the dorsal columns is higher than that of the grey substance; while it is lower than this from the second lumbar region to the end of the cord.

Between the upper portion of the first lumbar region and the lower portion of the third coccygeal region there is a total fall of 14 in the percentage of the dorsal columns. The fall is most rapid between the upper portion of the first lumbar and that of the sixth lumbar region. It occurs chiefly in the third, fourth, and fifth, and more particularly in the fourth lumbar. From the sixth lumbar region to the end of the cord the fall is very gradual, the percentage value being approximately the same through the sacral regions.

(b) *Percentage of the Vento-lateral Columns (A) (Chart IV, Table VII).*

The percentage of the ventro-lateral columns (A) to the cross-section of the cord falls from *ca.* 57 per cent. in the first lumbar region to *ca.* 36 per cent. in the first coccygeal, and rises from the middle portion of the latter region to 43 per cent. in the third coccygeal.

*Percentage of the Dorsal and of the Vento-lateral Columns to the
Cross-sections of the Cord.*

Table VII.—Percentage of the Dorsal and the Vento-Lateral Columns to the Cross-Sections of the Cord. The total area of each cross-section of the cord = 100 (Charts IV, VII, and VIII).

Region of cord.	Distance in cm. from uppermost section of I Lumbar region.	Percentage of the dorsal columns.	Mean percentage.	Percentage of the ventro-lateral columns.	Mean percentage.
Dorsal (thoracic)—					
VI	—	22·64	—	64·14	
XII	—	22·83	—	60·63	
Lumbar—					
I { Upper ...	0·142	22·07	22·68	57·48	56·60
{ Middle ...	0·268	23·06		57·19	
{ Lower ...	0·608	22·92		55·14	
II { Upper ...	0·846	22·67	22·15	52·55	52·51
{ Middle ...	1·058	22·03		52·22	
{ Lower ...	1·302	21·75		52·76	
III { Upper ...	1·558	21·81	21·25	50·38	50·32
{ Middle ...	1·681	21·32		50·22	
{ Lower ...	1·918	20·63		50·35	
IV { Upper ...	2·064	19·82	18·35	47·85	46·75
{ Middle ...	2·244	17·97		45·89	
{ Lower ...	2·484	17·26		46·52	
V { Upper ...	2·608	16·74	15·72	46·15	44·34
{ Middle ...	2·794	15·40		44·17	
{ Lower ...	2·944	15·01		42·70	
VI { Upper ...	3·154	13·45	13·59	42·52	42·94
{ Middle ...	3·205	13·78		43·63	
{ Lower ...	3·328	13·54		42·66	
VII { Upper ...	3·450	13·27	13·00	40·60	40·79
{ Middle ...	3·557	13·09		40·50	
{ Lower ...	3·642	13·05		41·27	
Sacral—					
I { Upper ...	3·782	12·18	11·69	41·91	41·58
{ Middle ...	3·906	11·70		41·28	
{ Lower ...	4·057	11·18		41·34	
II { Upper ...	4·197	11·29	11·82	41·45	41·09
{ Middle ...	4·316	12·01		41·22	
{ Lower ...	4·509	12·14		40·60	
III { Upper ...	4·623	11·67	12·03	41·67	40·07
{ Middle ...	4·723	12·62		39·56	
{ Lower ...	4·858	11·80		38·99	
IV { Upper ...	4·974	11·55	11·64	38·73	38·49
{ Middle ...	5·138	11·49		38·36	
{ Lower ...	5·312	11·87		38·37	
Coccygeal—					
I { Upper ...	5·486	10·04	10·11	36·62	36·63
{ Middle ...	5·622	10·67		36·19	
{ Lower ...	5·726	9·62		37·09	
II { Upper ...	5·847	9·80	9·77	38·87	38·31
{ Middle ...	5·939	10·01		37·69	
{ Lower ...	6·058	9·51		38·38	
III { Upper ...	6·174	8·08	7·92	39·52	42·52
{ Middle ...	6·278	7·54		44·49	
{ Lower ...	6·331	8·13		43·54	

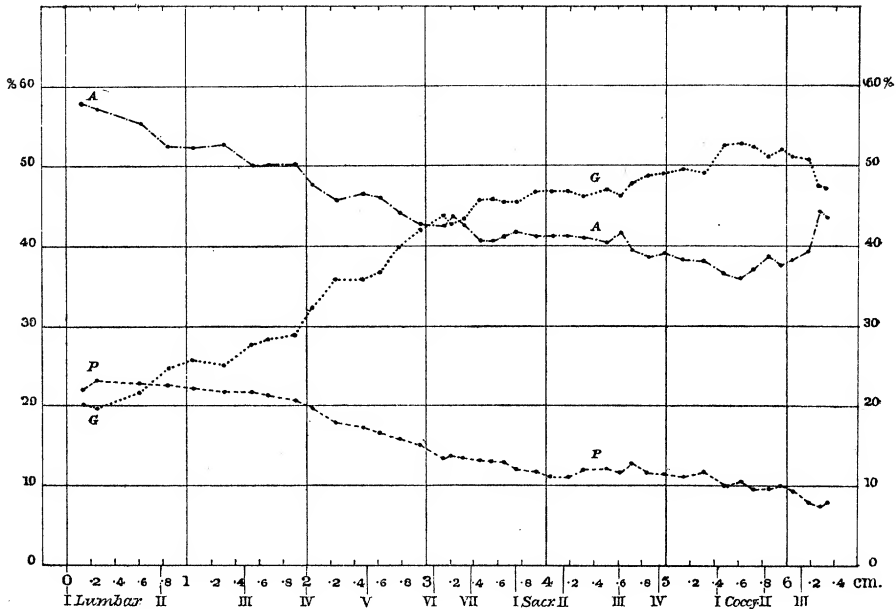


CHART IV.—Curves showing the Percentage Value of the Grey Substance and of the Dorsal and Ventro-lateral White Columns in the Cross-section of the Cord (Tables VI, VII).

The area of each cross-section of the cord = 100. The ordinates denote percentage value, the abscissæ the length of the cord in centimetres measured from the uppermost section of the first lumbar region. The numbers (I, II, III, etc.) mark approximately the cephalic end of the region of each pair of spinal nerves.

Percentage of grey substance G, dotted line.
 Percentage of dorsal white columns..... P, broken line.
 Percentage of ventro-lateral white columns ... A, line and dot.

The curve (A, Chart IV) shows alternate periods of falling value and a condition of equality or slight rise, especially between the first and seventh lumbar regions.*

Speaking generally, the fall in percentage is most rapid between the upper portion of the first lumbar and the lower portion of the fifth lumbar region. Taking the individual nerve regions, the most conspicuous fall occurs between the lower portion of the region of the third and that of the fifth lumbar nerve, it being most marked in the fifth.

The percentage value of the ventro-lateral columns (A) is equal to that of the grey substance (G) in the sixth lumbar region.

From the seventh lumbar to the third sacral region (upper portions) the percentage is practically the same.

This may indicate a segmental factor.

The rise, beginning in the middle portion of the first coccygeal, is continued through the second and third coccygeal regions. The percentage attained in the third coccygeal is equal to that in the fifth and sixth lumbar regions.

Hence it is seen that of the total fall of *ca.* 32 per cent. occurring in the percentage of the white substance (W) to the cross-sections of the cord, between the first lumbar and first coccygeal regions (upper portions), 11 is due to the fall in percentage of the dorsal columns (P), and 21 to that of the ventro-lateral columns (A), and that although the percentage value of both components of the white substance falls rapidly between the first and seventh lumbar regions, it is within these limits that the fall of the ventro-lateral columns so far exceeds that of the dorsal columns.

A further interesting point is the lack of correspondence between the fall of the ventro-lateral columns and that of the dorsal columns in the different nerve regions. This is especially noticeable between the first and seventh lumbar regions.

The comparatively slight rise seen in the percentage curve of the total white substance (W, Chart III) from the first to the third coccygeal region is accounted for by the continuance of the fall in percentage of the dorsal columns counteracting the rise in that of the ventro-lateral columns. The rise in the ventro-lateral columns (A) in the third coccygeal region is, however, more marked than the fall in the dorsal columns.

*Comparison Between the Section Area and the Percentage Value
of the Component Parts of the Cord.*

For the purpose of comparing the section area with the percentage value of any one component part of the cord, the mean figures of both have been taken in the region of each spinal nerve (see Tables II to VII) and the curves plotted in the same chart.

Both the sectional area (G) and the percentage value (*g*) of the grey substance increase from the first to the fifth lumbar region. From the fifth lumbar to the third coccygeal region the sectional area decreases, whereas the percentage value increases to the first coccygeal, but decreases slightly in the second, and to a somewhat greater extent in the third coccygeal region.

(a) Grey Substance. (Chart V, Tables II and VI.)

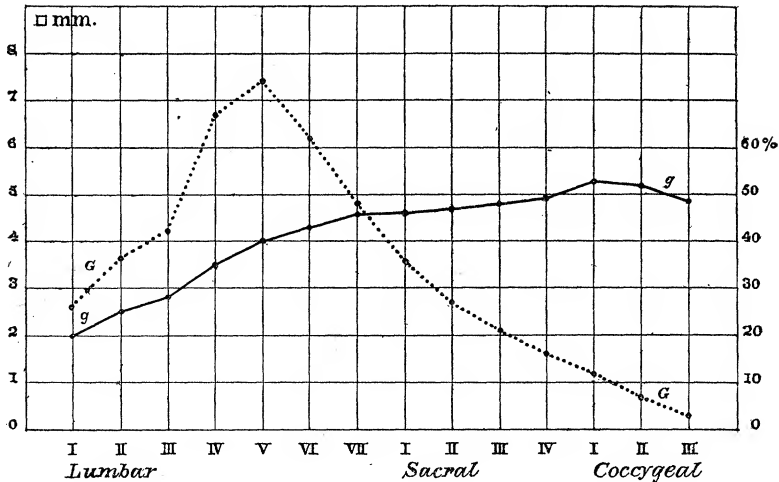


CHART V.—Curves showing the Mean Sectional Area (G, dotted line) and Percentage Value (g, continuous line) of the Grey Substance in the Cross-section of the Cord (Tables II, VI).

The ordinates on the left-hand side of the chart denote section area in square millimetres, and on the right-hand side percentage value. The abscissæ denote spinal nerve regions.

The sectional area of the white substance (W) increases from the first to the fourth lumbar region, whilst the percentage value (*w*) decreases.

Between the fourth and the seventh lumbar regions there is a decrease in both. From the seventh lumbar to the third sacral region the sectional area decreases, the percentage value remaining approximately the same.

From the third sacral to the first coccygeal there is a decrease in both, and from the first to the third coccygeal region the sectional area decreases, whilst the percentage value increases.

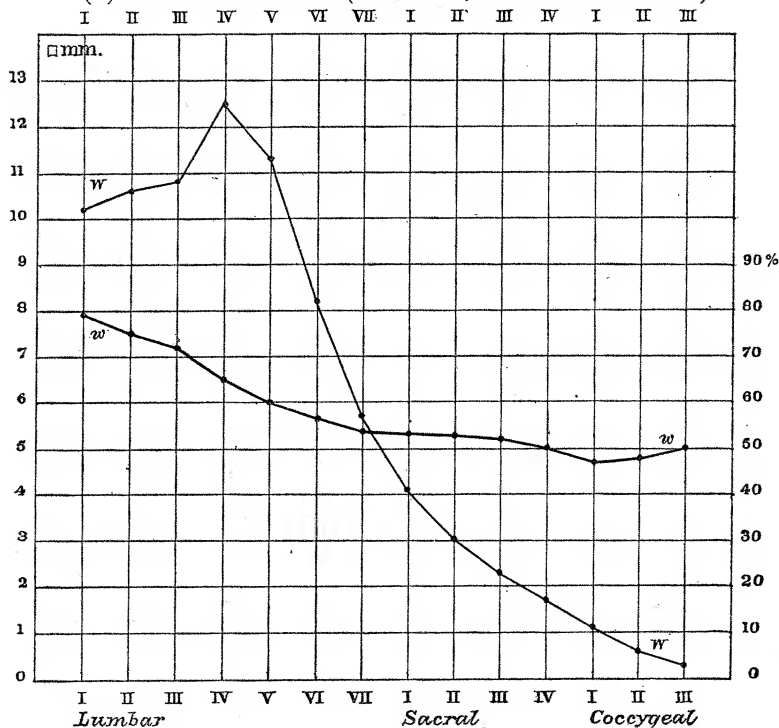
(b) *White Substance. (Chart VI, Tables III and VI.)*

CHART VI.—Curves showing the Mean Sectional Area (*W*, thin continuous line) and Percentage Value (*w*, thick continuous line) of the White Substance in the Cross-section of the Cord (Tables III, VI).

The abscissæ denote spinal nerve regions, the value of the ordinates given on the left-hand side of the chart is for section area in square millimetres. For the percentage, the value of the ordinates is given on the right-hand side.

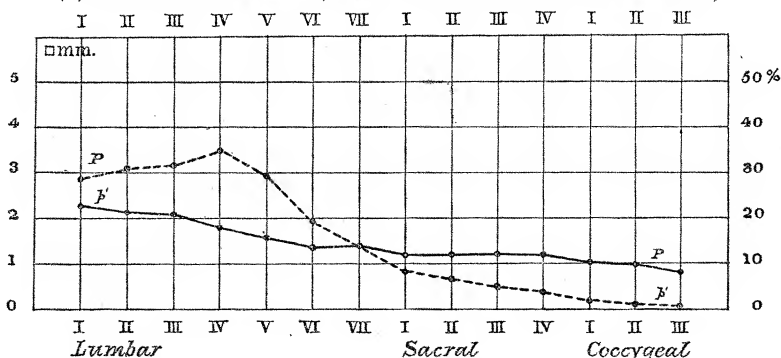
(c) *Dorsal Columns. (Chart VII, Tables IV and VII.)*

CHART VII.—Curves showing the Mean Sectional Area (*P*, dotted line), and the Mean Percentage Value (*p'*, continuous line) of the Dorsal Columns in the Cross-section of the Cord (Tables IV, VII).

The value of the ordinates given on the left-hand side of the chart indicates the section area in square millimetres, and on the right-hand side the percentage value. The abscissæ denote the spinal nerve regions.

The sectional area of the dorsal columns (P) increases from the first to the fourth lumbar region, the percentage value (p') at the same time decreases. From the fourth to the first sacral region there is a decrease in both; the sectional area continues to decrease from the first to the third sacral, whilst the percentage value increases slightly. From the third sacral to the third coccygeal region there is a decrease in both.

(d) *Ventro-Lateral Columns.* (Chart VIII, Tables V and VII.)

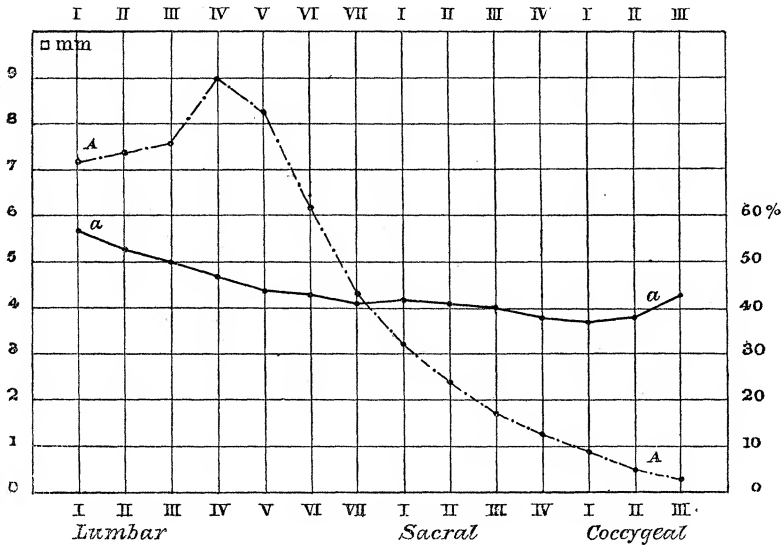


CHART VIII.—Curves showing the Mean Sectional Area (A, line and dot) and the Mean Percentage Value (α , continuous line) of the Ventro-lateral Columns in the Cross-section of the Cord (Tables V, VII).

For the section area in square millimetres the value of the ordinates is given on the left-hand side of the chart, and for the percentage on the right-hand side. The abscissæ denote the spinal nerve regions.

The sectional area of the ventro-lateral columns (A) increases from the first to the fourth lumbar region, whereas the percentage value (α) decreases.

From the fourth to the seventh lumbar there is a decrease in both. From the seventh lumbar to the first sacral the sectional area decreases and the percentage value increases.

From the second sacral to the first coccygeal region there is a decrease in both, and while the sectional area continues to decrease from the first to the third coccygeal region the percentage value increases, and to the greatest extent in the third coccygeal region.

A 3. *Ratio of the Total White Substance, and of the Dorsal and of the Ventro-Lateral Columns to the Grey Substance.*

Table VIII.—Ratio of the Total White Substance, and of the Dorsal and of the Ventro-lateral White Columns, to the Grey Substance taken as Unity in each Cross Section of the Cord (Chart IX).

Region of cord.	Distance in cm. from uppermost I Lumbar region.	White substance. Grey substance.	Mean.	Dorsal columns. Grey substance.	Mean.	Ventro-lateral columns. Grey substance.	Mean.
Dorsal (thoracic) —							
VI	—	6.78		1.77		5.01	
XII	—	5.06		1.38		3.67	
Lumbar—							
I { Upper	0.142	3.96	3.89	1.09	1.11	2.86	2.78
{ Middle	0.268	4.08		1.17		2.91	
{ Lower	0.608	3.62		1.06		2.56	
II { Upper	0.846	3.06	2.98	0.92	0.88	2.14	2.10
{ Middle	1.058	2.90		0.86		2.04	
{ Lower	1.302	2.98		0.87		2.11	
III { Upper	1.558	2.62	2.49	0.78	0.75	1.72	1.75
{ Middle	1.681	2.52		0.75		1.77	
{ Lower	1.918	2.47		0.72		1.75	
IV { Upper	2.064	2.10	1.88	0.61	0.53	1.49	1.35
{ Middle	2.244	1.77		0.50		1.27	
{ Lower	2.484	1.77		0.48		1.29	
V { Upper	2.608	1.72	1.53	0.46	0.40	1.26	1.13
{ Middle	2.794	1.49		0.39		1.10	
{ Lower	2.944	1.37		0.36		1.01	
VI { Upper	3.154	1.28	1.31	0.31	0.31	0.97	0.99
{ Middle	3.205	1.35		0.32		1.03	
{ Lower	3.328	1.29		0.31		0.98	
VII { Upper	3.450	1.18	1.18	0.29	0.29	0.89	0.89
{ Middle	3.557	1.17		0.28		0.88	
{ Lower	3.642	1.20		0.29		0.91	

Sacral— I { Upper Middle Lower	3.782	1.19	0.27	0.25	0.92	0.90
	3.906	1.14	0.25		0.89	
	4.057	1.11	0.23		0.88	
	4.197	1.12	0.24		0.88	
II { Upper Middle Lower	4.316	1.15	0.26	0.25	0.89	0.88
	4.509	1.12	0.26		0.86	
	4.623	1.14	0.25		0.89	
	4.723	1.09	0.26	0.25	0.83	0.84
III { Upper Middle Lower	4.858	1.04	0.24		0.79	
	4.974	1.02	0.23		0.79	
	5.138	1.00	0.23	0.23	0.77	0.78
	5.312	1.02	0.24		0.78	
Coccygeal— I { Upper Middle Lower	5.486	0.89	0.19	0.20	0.69	0.70
	5.622	0.89	0.21		0.69	
	5.726	0.89	0.19		0.71	
	5.847	0.96	0.19		0.77	
II { Upper Middle Lower	5.989	0.91	0.19	0.19	0.72	0.75
	6.058	0.93	0.18		0.75	
	6.174	0.94	0.16		0.78	
	6.278	1.09	0.16	0.17	0.94	0.88
III { Upper Middle Lower	6.331	1.09	0.17		0.92	

The ratio $\frac{\text{white substance}}{\text{grey substance}}$ having been determined for the upper, middle, and lower portions of the region of each spinal nerve, a mean of the three ratios has been employed in the curve to represent the ratio of the region.*

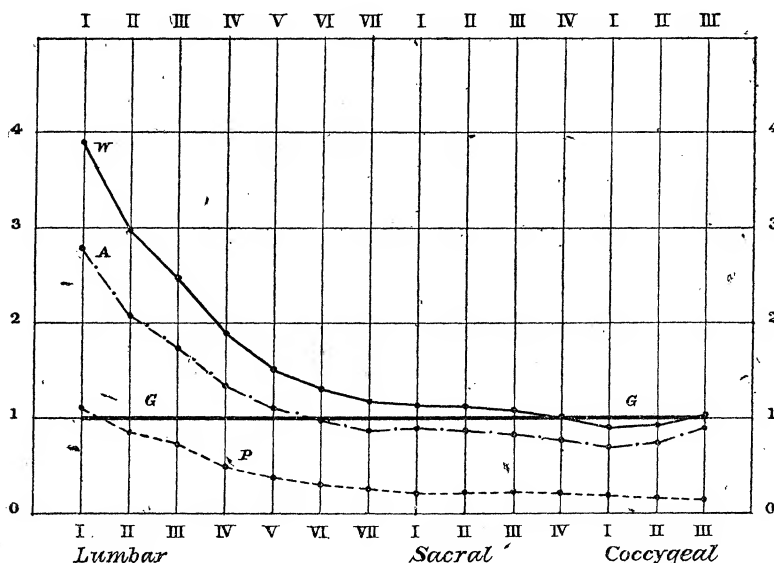


CHART IX.—Curves showing the Ratio of the total White Substance (W, continuous line), of the Dorsal White Columns (P, broken line), and of the Ventro-lateral White Columns (A, line and dot) to the Grey Substance (G).

The grey substance is taken as unity in each cross-section of the cord. Mean results are plotted (Table VIII). The abscissæ denote the spinal nerve regions, the ordinates the ratio at the corresponding regions.

(a) Ratio $\frac{\text{white substance (W)}}{\text{grey substance (G)}}$ Chart IX, Table VIII.

The ratio $\frac{\text{total white substance (W)}}{\text{grey substance (G)}}$ decreases continuously from the first lumbar to the first coccygeal region. From the first to the third coccygeal region a very slight increase occurs.

The decrease in the ratio is very rapid from the first to the seventh lumbar region, and is most conspicuous in the first three lumbar regions. In the seventh lumbar and through the first three sacral regions the decrease in the ratio is scarcely perceptible. In the fourth sacral region the ratio is as 1 : 1, and while in the first and second coccygeal regions it is slightly less, equality is again reached in the third coccygeal region.

* The same remark applies to all subsequent curves illustrating ratio.

(b) Ratio $\frac{\text{dorsal columns (P)}}{\text{grey substance (G)}}$ (Chart IX, Table VIII).

The curve (P) representing the ratio $\frac{\text{dorsal columns}}{\text{grey substance}}$ differs from that of the ventro-lateral columns (A) in the total fall being much less pronounced.

The ratio starting as only slightly more than 1 : 1 in the first lumbar region falls gradually, and is less than 1 : 1 in the second lumbar region, and throughout the remainder of the cord. Through the first three sacral regions the ratio is approximately the same. The grey substance being taken as unity, the index of the fall from the first lumbar to the third coccygeal region is only 0.95, the principal decrease occurring in the lumbar regions (0.82) and chiefly in those of the first five lumbar nerves.

(c) Ratio $\frac{\text{ventro-lateral columns (A)}}{\text{grey substance (G)}}$ (Chart IX, Table VIII).

The curve (A) indicating the ratio $\frac{\text{ventro-lateral columns}}{\text{grey substance}}$ resembles in its general configuration the curve (W) denoting the ratio $\frac{\text{total white substance}}{\text{grey substance}}$.

The ratio decreases rapidly from the first to the seventh lumbar region, the decrease being most marked in the regions of the first five lumbar nerves. In the seventh lumbar and first and second sacral regions the ratio is almost the same. A slight decrease from the third sacral to the first coccygeal region is followed by a slight increase in the lower coccygeal regions, the ratio being approximately the same in the third coccygeal as in the seventh lumbar region.

Although the absolute fall in the ratio $\frac{\text{ventro-lateral columns}}{\text{grey substance}}$ is much greater than that in the ratio $\frac{\text{dorsal columns}}{\text{grey substance}}$, relatively the variation of the latter is considerably greater.

This is seen in Chart X, where the ordinates indicate the relative values of the ratios, when the ratio for the first lumbar region is in each case taken as 10 (Table IX).

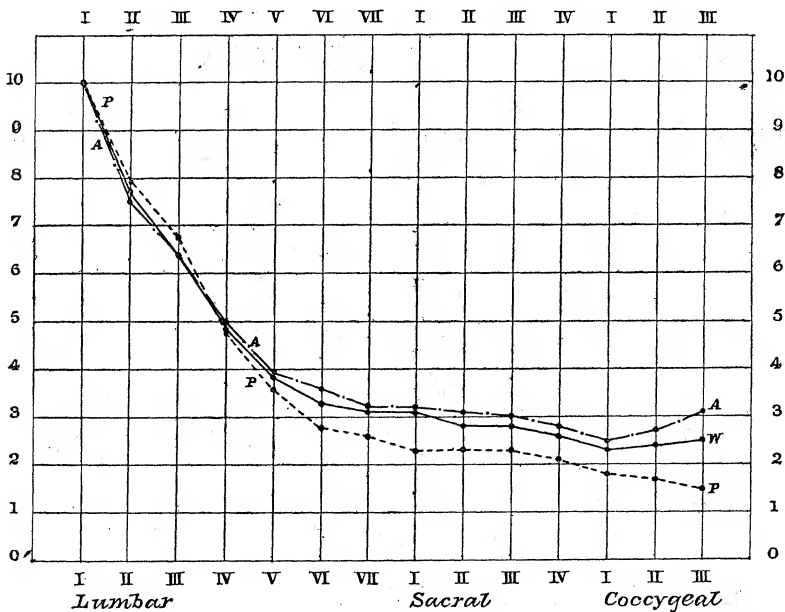


CHART X.—Curves showing the Relative Values of the Ratios $\frac{\text{Total White Substance}}{\text{Grey Substance}}$ (W, continuous line), $\frac{\text{Dorsal Columns}}{\text{Grey Substance}}$ (P, broken line), $\frac{\text{Ventro-lateral Columns}}{\text{Grey Substance}}$ (A, line and dot) (Table IX).

The ratio in the first lumbar region is in each case taken as 10 (see Table VIII). The abscissæ denote spinal nerve regions, the ordinates relative value at corresponding regions.

Table IX.—Relative Values of the Ratios $\frac{\text{Total White Substance}}{\text{Grey Substance}}$, $\frac{\text{Dorsal Columns}}{\text{Grey Substance}}$, and $\frac{\text{Ventro-lateral Columns}}{\text{Grey Substance}}$. The ratio in the I Lumbar region is in each case taken as 10 (Chart X).

Region of cord.	Total white substance.	Dorsal columns.	Ventro-lateral columns.
Lumbar—			
I	10.0	10.0	10.0
II	7.7	7.9	7.5
III	6.4	6.8	6.4
IV	4.9	4.8	5.0
V	3.8	3.6	3.9
VI	3.3	2.8	3.6
VII	3.1	2.6	3.2
Sacral—			
I	3.1	2.3	3.2
II	2.8	2.3	3.1
III	2.8	2.3	3.0
IV	2.6	2.1	2.8
Coccygeal—			
I	2.3	1.8	2.5
II	2.4	1.7	2.7
III	2.5	1.5	3.1

A4. Ratio of the Dorsal and of the Vento-lateral Columns to the White Substance as a Whole.

Table X.—Ratio of the Dorsal Columns and of the Vento-lateral Columns to the Total White Substance taken as Unity in each Cross-section of the Cord (Chart XI).

Region of cord.	Distance in cm. from uppermost section of I Lumbar region.	Dorsal columns Total white substance.	Mean.	Vento-lateral columns Total white substance.	Mean.
Dorsal (thoracic)—					
VI.....	—	0·261	—	0·769	
XII.....	—	0·274	—	0·726	
Lumbar—					
I { Upper ...	0·142	0·278	0·286	0·722	0·714
{ Middle...	0·268	0·287		0·713	
{ Lower ...	0·608	0·294		0·706	
II { Upper ...	0·846	0·301	0·297	0·699	0·703
{ Middle...	1·058	0·297		0·703	
{ Lower ...	1·302	0·292		0·708	
III { Upper ...	1·558	0·301	0·297	0·698	0·703
{ Middle...	1·681	0·298		0·702	
{ Lower ...	1·918	0·291		0·709	
IV { Upper ...	2·064	0·293	0·282	0·707	0·718
{ Middle...	2·244	0·281		0·719	
{ Lower ...	2·484	0·271		0·729	
V { Upper ...	2·608	0·266	0·262	0·734	0·738
{ Middle...	2·794	0·258		0·741	
{ Lower ...	2·944	0·260		0·740	
VI { Upper ...	3·154	0·240	0·240	0·760	0·760
{ Middle...	3·205	0·240		0·760	
{ Lower ...	3·328	0·241		0·759	
VII { Upper ...	3·450	0·246	0·244	0·754	0·756
{ Middle...	3·557	0·244		0·756	
{ Lower ...	3·642	0·240		0·760	
Sacral—					
I { Upper ...	3·782	0·225	0·220	0·774	0·780
{ Middle...	3·906	0·221		0·779	
{ Lower ...	4·057	0·213		0·787	
II { Upper ...	4·197	0·214	0·224	0·785	0·776
{ Middle...	4·316	0·226		0·774	
{ Lower ...	4·509	0·231		0·769	
III { Upper ...	4·623	0·219	0·231	0·781	0·769
{ Middle...	4·723	0·242		0·758	
{ Lower ...	4·858	0·232		0·768	
IV { Upper ...	4·974	0·230	0·232	0·770	0·768
{ Middle...	5·138	0·231		0·769	
{ Lower ...	5·312	0·236		0·764	
Coccygeal—					
I { Upper ...	5·486	0·215	0·216	0·785	0·784
{ Middle...	5·622	0·228		0·772	
{ Lower ...	5·726	0·206		0·794	
II { Upper ...	5·847	0·201	0·203	0·798	0·796
{ Middle...	5·939	0·210		0·790	
{ Lower ...	6·058	0·199		0·801	
III { Upper ...	6·174	0·170	0·157	0·830	0·843
{ Middle...	6·278	0·145		0·855	
{ Lower ...	6·331	0·157		0·843	

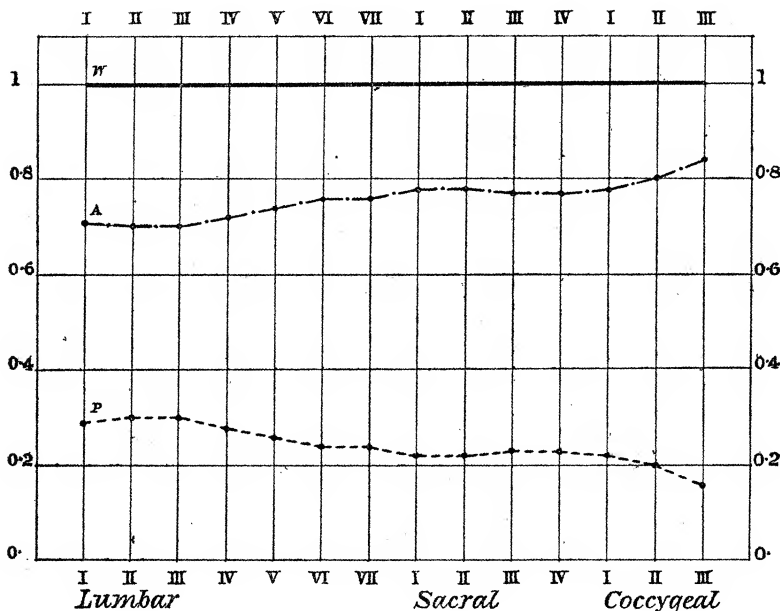


CHART XI.—Curves showing the Ratio of the Dorsal Columns (P, broken line) and of the Ventro-lateral Columns (A, line and dot) to the White Substance as a whole (W).

The white substance in each cross-section of the cord is taken as unity. Mean figures are plotted (Table X). The abscissæ denote the spinal nerve regions, the ordinates the ratio at the corresponding regions.

The ratio $\frac{\text{dorsal columns (P)}}{\text{white substance (W)}}$ (Chart XI, Table X) increases slightly from the first lumbar region to the second, and remains the same in the third. It decreases from the fourth lumbar to the first sacral region, being the same in both the sixth and seventh lumbar. Through the sacral regions and the first coccygeal the ratio varies very little; it again decreases in the lower coccygeal regions.

The two curves being complementary, the above remarks apply inversely to the ratio $\frac{\text{ventro-lateral columns (A)}}{\text{white substance (W)}}$ (Chart XI, Table X).

A5. *Ratio of the Ventro-lateral Columns to the Dorsal Columns.*

Table XI.—Ratio of the Ventro-lateral Columns to the Dorsal Columns taken as Unity in each Cross-section of the Cord (Chart XII).

Region of cord.	Distance in cm. from uppermost section of I Lumbar region.	Ventro-lateral columns. Dorsal columns.	Mean.
Dorsal—			
VI	—	2·83	
XII	—	2·56	
Lumbar—			
I { Upper	0·142	2·61	2·50
{ Middle	0·268	2·48	
{ Lower	0·608	2·40	
II { Upper	0·846	2·32	2·37
{ Middle	1·058	2·37	
{ Lower	1·302	2·43	
III { Upper	1·558	2·31	2·37
{ Middle	1·681	2·36	
{ Lower	1·918	2·41	
IV { Upper	2·064	2·42	2·56
{ Middle	2·244	2·55	
{ Lower	2·484	2·70	
V { Upper	2·608	2·75	2·82
{ Middle	2·794	2·86	
{ Lower	2·944	2·84	
VI { Upper	3·154	3·16	3·16
{ Middle	3·205	3·16	
{ Lower	3·328	3·15	
VII { Upper	3·450	3·05	3·10
{ Middle	3·557	3·09	
{ Lower	3·642	3·16	
Sacral—			
I { Upper	3·782	3·44	3·55
{ Middle	3·906	3·51	
{ Lower	4·057	3·70	
II { Upper	4·197	3·67	3·48
{ Middle	4·316	3·43	
{ Lower	4·509	3·34	
III { Upper	4·623	3·57	3·34
{ Middle	4·723	3·14	
{ Lower	4·858	3·30	
IV { Upper	4·974	3·37	3·29
{ Middle	5·138	3·31	
{ Lower	5·312	3·19	
Coccygeal—			
I { Upper	5·486	3·65	3·63
{ Middle	5·622	3·39	
{ Lower	5·726	3·85	
II { Upper	5·847	3·97	3·93
{ Middle	5·939	3·77	
{ Lower	6·058	4·04	
III { Upper	6·174	4·89	5·38
{ Middle	6·278	5·90	
{ Lower	6·331	5·35	

The ratio $\frac{\text{ventro-lateral columns (A)}}{\text{dorsal columns (P)}}$ (Chart XII, Table XI) falls slightly from the first to the second lumbar region, is constant in the third, and

increases from the fourth to the first sacral region, a slight fall being noticed in the seventh lumbar. The ratio decreases in the second, third, and fourth sacral regions, but increases again through the coccygeal regions, the increase being very marked in the third.

Comparing the ratio of the two columns in different regions with that in the first lumbar, it is seen that the ratio is 1·4 and 1·6 times as great in the first sacral and second coccygeal regions respectively, and becomes 2·1 times as great in the third coccygeal.

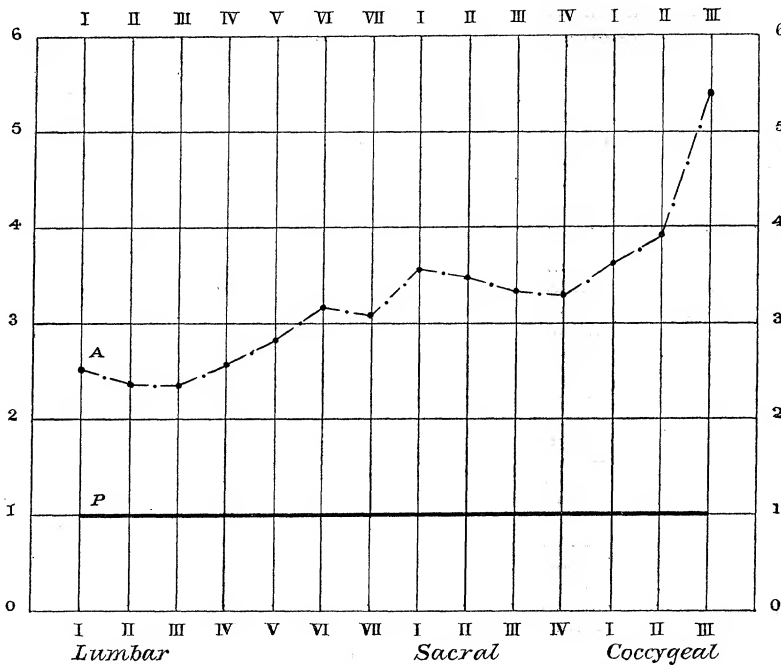


CHART XII.—Curves showing the Ratio of the Ventro-lateral Columns (A, line and dot) to the Dorsal Columns (P).

The dorsal columns taken as unity in each cross-section of the cord. Mean results are plotted (Table XI). The abscissæ denote spinal nerve regions, the ordinates the ratio at the corresponding regions.

B1. *Section Area of the Dorsal and of the Ventral Horns of the Grey Substance in the Region of each Spinal Nerve.*

A remarkable difference is observable in the form of the two curves representing the section areas of the dorsal and the ventral horns of the grey substance.*

The curve indicating the dorsal horns (D) (Chart XIII) is comparatively flat throughout the portion of the cord examined, whilst that denoting the

* For definition of terms "dorsal" and "ventral horns" see p. 90.

ventral horns (V), with its marked rise and fall, resembles in every way the curve illustrating the section area of the grey substance as a whole.

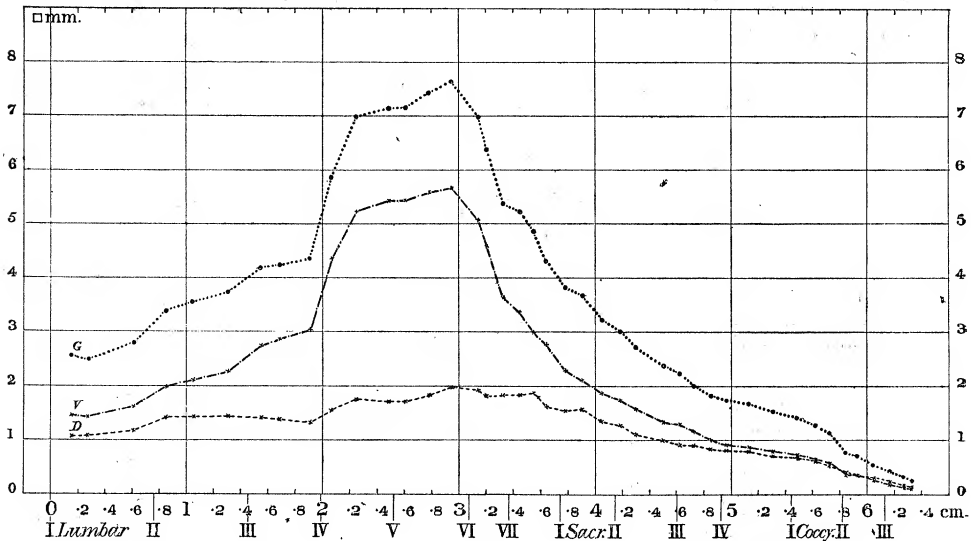


CHART XIII.—Curves showing the Section Areas of the Grey Substance and of the Dorsal and the Ventral Horns of the same (Tables II, XII, XIII).

The ordinates denote section area in square millimetres, and the abscissæ the length of the cord in centimetres measured from the uppermost section of the first lumbar region. The Roman figures mark approximately the cephalic end of the region of each pair of spinal nerves.

Grey substance as a whole.....	G, dotted line.
Dorsal horns.....	D, interrupted line and cross.
Ventral horns	V, line, dot, and cross.

(a) *Section Area of the Dorsal Horns.*

The section area of the dorsal horns (Chart XIII D, Table XII) increases from the first to the fifth lumbar region, and decreases from the lower portion of the fifth to the end of the cord. The actual increase between the first and fifth lumbar regions amounts to 0.87 sq. mm. (1.1—1.97 sq. mm.). The section area at its maximum (V L, lower) is thus almost twice as great as in the first lumbar region.

It will be observed that the maximum is reached in the same region, as the maximum section area of the grey substance (G).

Both the increase and decrease in the section area of the dorsal horns take place gradually, but the decrease is more rapid than the increase. The section area varies very little in the first lumbar region, it becomes rather

larger in the upper portion of the second, and remains much the same through this and the third. The chief increase occurs between the lower portion of the third and that of the fifth lumbar region, and is most marked in the fifth.

Table XII.—Section Area of the Dorsal Horns (Chart XIII).

Region of cord.	Distance in cm. from uppermost section of I Lumbar region.	Planimeter measurement in sq. cm.	Actual area as calculated in sq. mm.	Mean.
Dorsal (thoracic)—				
VI	—	2.28	0.570	
XII	—	3.16	0.790	
Lumbar—				
I { Upper	0.142	4.38	1.095	1.108
I { Middle	0.268	4.28	1.070	
I { Lower	0.608	4.68	1.170	
II { Upper	0.846	5.68	1.420	1.438
II { Middle	1.058	5.76	1.440	
II { Lower	1.302	5.82	1.455	
III { Upper	1.558	5.64	1.410	1.365
III { Middle	1.681	5.50	1.375	
III { Lower	1.918	5.24	1.310	
IV { Upper	2.064	6.02	1.505	1.657
IV { Middle	2.244	7.02	1.755	
IV { Lower	2.484	6.85	1.712	
V { Upper	2.608	6.82	1.705	1.840
V { Middle	2.794	7.38	1.845	
V { Lower	2.944	7.88	1.970	
VI { Upper	3.154	7.64	1.910	1.812
VI { Middle	3.205	7.24	1.810	
VI { Lower	3.328	6.86	1.715	
VII { Upper	3.450	7.34	1.835	1.781
VII { Middle	3.557	7.49	1.873	
VII { Lower	3.642	6.54	1.635	
Sacral—				
I { Upper	3.782	6.16	1.540	1.492
I { Middle	3.906	6.32	1.580	
I { Lower	4.057	5.42	1.355	
II { Upper	4.197	5.14	1.285	1.412
II { Middle	4.316	4.46	1.115	
II { Lower	4.509	4.10	1.025	
III { Upper	4.623	3.74	0.9350	0.8950
III { Middle	4.723	3.64	0.9100	
III { Lower	4.858	3.36	0.8400	
IV { Upper	4.974	3.28	0.8200	0.7766
IV { Middle	5.138	3.18	0.7950	
IV { Lower	5.312	2.86	0.7150	
Coccygeal—				
I { Upper	5.486	2.76	0.6900	0.6166
I { Middle	5.622	2.46	0.6150	
I { Lower	5.726	2.18	0.5450	
II { Upper	5.847	6.40	0.4000	0.3502
II { Middle	5.939	5.89	0.3681	
II { Lower	6.058	4.52	0.2825	
III { Upper	6.174	0.96	0.2400	0.1868
III { Middle	6.278	2.86	0.1787	
III { Lower	6.331	0.59	0.1475	

The decrease in section area is very slight between the fifth and the middle portion of the seventh lumbar region. It is accentuated between the seventh lumbar (middle portion) and the third sacral region, and, with the exception of being marked between the first and second coccygeal regions, is continued in a regular manner to the end of the cord.

In the first coccygeal region the section area of the dorsal horns (D) is almost equal to that of the ventral horns (V), and is slightly greater in the second and third coccygeal regions.

(b) *Section Area of the Ventral Horns.*

The section area of the ventral horns (Chart XIII V, Table XIII) increases from the first to the lower portion of the fifth lumbar region, where the maximum (5.68 sq. mm.) is reached. The maximum is thus found in the same region (VL) as the maximum section areas of the dorsal horns (D), and of the grey substance as a whole (G).

The section area of the ventral horns (V) decreases from the fifth lumbar region to the end of the cord.

The increase in section area is very gradual from the first to the lower part of the third lumbar region, but becomes very marked between the latter and the lower part of the fifth lumbar region, three-fifths of the whole increase occurring here. The most rapid increase is between the third and fourth and in the fourth lumbar region. Throughout the fifth lumbar the section area is nearly four times as great as that in the first lumbar region.

The decrease in section area is more rapid than the increase, and is very marked between the lower portion of the fifth and that of the sixth lumbar region. From the seventh lumbar region to the end of the cord, the decrease continues in a more regular manner and is least marked between the third sacral and second coccygeal regions.

The section area of the ventral horns (V) in the seventh lumbar region (*ca.* 3 sq. mm.) is much the same as that in the third lumbar region, and in the second sacral (*ca.* 1.5 sq. mm.) it is much the same as in the first lumbar region.

Table XIII.—Section Area of the Ventral Horns (Chart XIII).

Region of cord.	Distance in cm. from uppermost section of I Lumbar region.	Planimeter measurement in sq. cm.	Actual area as calculated in sq. mm.	Mean.
Dorsal (thoracic)—				
VI	—	2·70	0·675	
XII	—	4·40	1·100	
Lumbar—				
I { Upper	0·142	5·84	1·460	1·495
I { Middle	0·268	5·66	1·415	
I { Lower	0·608	6·44	1·610	
II { Upper	0·846	7·90	1·975	2·115
II { Middle	1·058	8·44	2·210	
II { Lower	1·302	9·04	2·260	
III { Upper	1·558	11·00	2·750	2·875
III { Middle	1·681	11·40	2·850	
III { Lower	1·918	12·10	3·025	
IV { Upper	2·064	17·40	4·350	4·993
IV { Middle	2·244	20·84	5·210	
IV { Lower	2·484	21·68	5·420	
V { Upper	2·608	21·78	5·445	5·570
V { Middle	2·794	22·36	5·590	
V { Lower	2·944	22·70	5·675	
VI { Upper	3·154	20·26	5·065	4·423
VI { Middle	3·205	18·25	4·563	
VI { Lower	3·328	14·56	3·640	
VII { Upper	3·450	13·50	3·375	3·028
VII { Middle	3·557	11·96	2·990	
VII { Lower	3·642	10·88	2·720	
Sacral—				
I { Upper	3·782	9·12	2·280	2·082
I { Middle	3·906	8·42	2·105	
I { Lower	4·057	7·44	1·860	
II { Upper	4·197	7·00	1·750	1·555
II { Middle	4·316	6·28	1·570	
II { Lower	4·509	5·38	1·345	
III { Upper	4·623	5·16	1·290	1·155
III { Middle	4·723	4·70	1·175	
III { Lower	4·858	4·00	1·000	
IV { Upper	4·974	3·70	0·9250	0·8650
IV { Middle	5·138	3·48	0·8700	
IV { Lower	5·312	3·20	0·8000	
Coccygeal—				
I { Upper	5·486	2·90	0·7250	0·6500
I { Middle	5·622	2·60	0·6500	
I { Lower	5·726	2·30	0·5750	
II { Upper	5·847	5·94	0·3712	0·3295
II { Middle	5·939	5·66	0·3537	
II { Lower	6·058	4·22	0·2637	
III { Upper	6·174	0·74	0·1850	0·1379
III { Middle	6·278	2·06	0·1287	
III { Lower	6·331	0·40	0·1000	

B2. Percentage of the Ventral and of the Dorsal Horns to the Total Grey Substance in the Cross-section of the Cord.

Table XIV.—Percentage Values of the Dorsal and of the Ventral Horns in the Total Grey Substance. The total area of the grey substance in each cross-section of the cord = 100 (Chart XIV).

Region of cord.	Distance in cm. from uppermost section of I Lumbar region.	Percentage of dorsal horns.	Mean.	Percentage of ventral horns.	Mean.
Dorsal (thoracic)—					
VI	—	45·78	—	54·22	
XII	—	41·80	—	58·20	
Lumbar—					
I { Upper ...	0·142	42·86	42·67	57·14	57·33
{ Middle ...	0·268	43·06		56·94	
{ Lower ...	0·608	42·09		57·91	
II { Upper ...	0·846	41·83	40·52	58·17	59·48
{ Middle ...	1·058	40·56		59·44	
{ Lower ...	1·302	39·17		60·83	
III { Upper ...	1·558	33·89	32·22	66·11	67·78
{ Middle ...	1·681	32·54		67·46	
{ Lower ...	1·918	30·22		69·78	
IV { Upper ...	2·064	25·70	24·97	74·30	75·02
{ Middle ...	2·244	25·20		74·80	
{ Lower ...	2·484	24·00		75·96	
V { Upper ...	2·608	23·85	24·81	76·15	75·19
{ Middle ...	2·794	24·82		75·18	
{ Lower ...	2·944	25·77		74·23	
VI { Upper ...	3·154	27·38	29·27	72·62	70·73
{ Middle ...	3·205	28·40		71·60	
{ Lower ...	3·328	32·03		67·97	
VII { Upper ...	3·450	35·22	37·09	64·78	62·91
{ Middle ...	3·557	38·51		61·49	
{ Lower ...	3·642	37·54		62·46	
Sacral—					
I { Upper ...	3·782	40·31	41·78	59·69	58·22
{ Middle ...	3·906	42·88		57·12	
{ Lower ...	4·057	42·15		57·85	
II { Upper ...	4·197	42·34	42·38	57·66	57·62
{ Middle ...	4·316	41·53		58·47	
{ Lower ...	4·509	43·25		56·75	
III { Upper ...	4·623	42·02	43·77	57·98	56·23
{ Middle ...	4·723	43·65		56·35	
{ Lower ...	4·858	45·65		54·35	
IV { Upper ...	4·974	46·99	47·31	53·01	52·69
{ Middle ...	5·138	47·75		52·25	
{ Lower ...	5·312	47·19		52·81	
Coccygeal—					
I { Upper ...	5·486	48·76	48·81	51·24	51·19
{ Middle ...	5·622	49·01		50·99	
{ Lower ...	5·726	48·66		51·34	
II { Upper ...	5·847	51·86	51·66	48·14	48·34
{ Middle ...	5·939	51·38		48·62	
{ Lower ...	6·058	51·72		48·28	
III { Upper ...	6·174	56·47	58·07	43·53	41·93
{ Middle ...	6·278	58·13		41·87	
{ Lower ...	6·331	59·60		40·40	

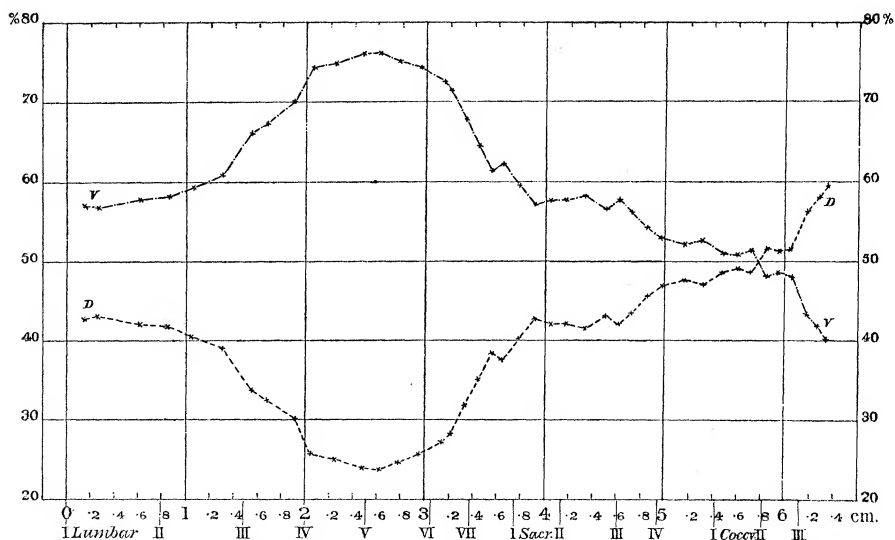


CHART XIV.—Curves showing the Percentage Values of the Ventral and of the Dorsal Horns in the Total Grey Substance.

The total area of the grey substance in each cross-section of the cord is taken as 100. The ordinates denote percentage value, the abscissæ the length of the cord in centimetres measured from the uppermost section of the first lumbar region.

Percentage of ventral horns..... V, line, dot, and cross.

Percentage of dorsal horns D, broken line and cross.

The percentage of the ventral horns (V) (Chart XIV, Table XIV) to the total grey substance in the cross-section of the cord increases to a very marked extent between the first lumbar and the upper portion of the fifth lumbar region, where the maximum (76 per cent.) is reached. The absolute rise is 19 per cent. The percentage decreases from the upper portion of the fifth lumbar region to the end of the cord, the absolute fall to the third coccygeal region amounting to *ca.* 36 per cent.

Inversely, the percentage of the dorsal horns decreases from the first to the fifth lumbar region, and increases from the latter region to the end of the cord, the maximum (59 per cent.) being reached in the region of the third coccygeal nerve.

The rise in the percentage of the ventral horns is very rapid between the lower portion of the second lumbar region and the upper portion of the fourth.

The fall in percentage is most marked between the fifth lumbar and the first sacral region (middle portion), and occurs chiefly in the sixth lumbar. It again becomes marked between the second and third coccygeal, and in the latter region.

Inversely, the same remarks apply to the curve representing the percentage of the dorsal horns to the total grey substance in the cross-section of the cord.

B3. *Ratio of the Ventral to the Dorsal Horns.*

Table XV.—Ratio of the Ventral to the Dorsal Horns taken as Unity in each Cross-section of the Cord (Chart XV).

Region of cord.	Distance in cm. from uppermost section of I Lumbar region.	Ventral horns. Dorsal horns.	Mean.
Dorsal (thoracic)—			
VI	—	1·84	
XII	—	1·39	
Lumbar—			
I { Upper	0·142	1·33	1·35
{ Middle	0·268	1·33	
{ Lower	0·608	1·38	
II { Upper	0·846	1·39	1·47
{ Middle	1·058	1·47	
{ Lower	1·302	1·55	
III { Upper	1·558	1·95	2·11
{ Middle	1·681	2·07	
{ Lower	1·918	2·31	
IV { Upper	2·064	2·89	3·01
{ Middle	2·244	2·97	
{ Lower	2·484	3·16	
V { Upper	2·608	3·19	3·03
{ Middle	2·794	3·03	
{ Lower	2·944	2·88	
VI { Upper	3·154	2·65	2·43
{ Middle	3·205	2·52	
{ Lower	3·328	2·12	
VII { Upper	3·450	1·84	1·70
{ Middle	3·557	1·60	
{ Lower	3·642	1·66	
Sacral—			
I { Upper	3·782	1·48	1·40
{ Middle	3·906	1·33	
{ Lower	4·057	1·37	
II { Upper	4·197	1·36	1·36
{ Middle	4·316	1·41	
{ Lower	4·509	1·31	
III { Upper	4·623	1·38	1·29
{ Middle	4·723	1·29	
{ Lower	4·858	1·19	
IV { Upper	4·974	1·13	1·11
{ Middle	5·138	1·09	
{ Lower	5·312	1·12	
Coccygeal—			
I { Upper	5·486	1·05	1·05
{ Middle	5·622	1·06	
{ Lower	5·726	1·05	
II { Upper	5·847	0·928	0·933
{ Middle	5·939	0·961	
{ Lower	6·058	0·911	
III { Upper	6·174	0·771	0·723
{ Middle	6·278	0·720	
{ Lower	6·331	0·678	

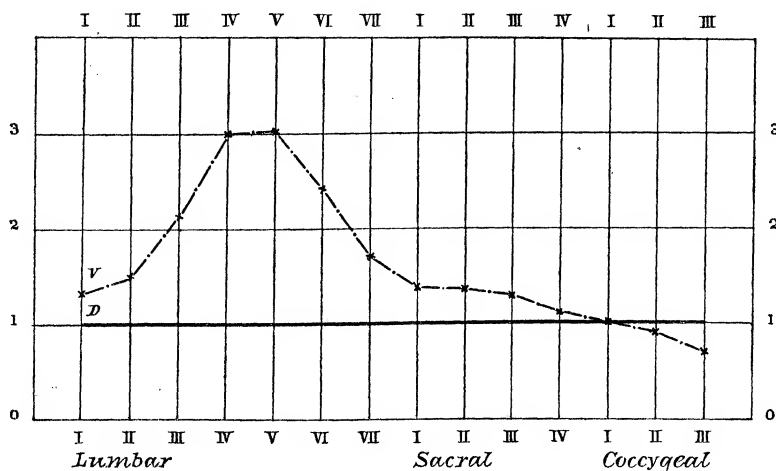


CHART XV.—Curve showing the Ratio of the Ventral Horns (V, line, dot, and cross) to the Dorsal Horns (D).

The dorsal horns taken as unity in each cross-section of the cord. Mean results are plotted (Table XV). The abscissæ denote spinal nerve regions, the ordinates ratio at corresponding regions.

The ratio $\frac{\text{ventral horns (V)}}{\text{dorsal horns (D)}}$ increases from the first to the fourth lumbar region, and is approximately the same in the fourth and fifth.

From the fifth lumbar region downwards to the end of the cord the ratio decreases, being as 1 : 1 in the first coccygeal region.

The ratio increases very rapidly in both the third and fourth lumbar regions. It decreases very rapidly in the sixth and seventh lumbar and first sacral regions, and more especially in the seventh lumbar.

The ratio $\frac{\text{ventral horns (V)}}{\text{dorsal horns (D)}}$ being approximately the same in the second sacral and first lumbar regions, the decrease between the fifth lumbar and second sacral region is seen to be less rapid than the corresponding increase between the first and fifth lumbar regions.

B4. *Ratio of the Dorsal and of the Ventral Horns of the Grey Substance to the Total Area of the Cross-section of the Cord.*

Since the percentage of grey substance to the cross-section of the cord and the ratio $\frac{\text{ventral horns}}{\text{dorsal horns}}$ have already been represented graphically in Charts III (G) and XV, no curves accompany the following table (XVI) giving the ratios $\frac{\text{dorsal horns}}{\text{total area of cross-section}}$, $\frac{\text{ventral horns}}{\text{total area of cross-section}}$.

Table XVI.—Ratio of the Dorsal and of the Ventral Horns of the Grey Substance to the Area of the Cross-section of the Cord taken as Unity.

Region of cord.	Distance in cm. from uppermost section of I Lumbar region.	Dorsal horns Area of cross- section of cord.	Mean.	Ventral horns Area of cross- section of cord.	Mean.
Dorsal (thoracic)—					
VI	—	0·0584	—	0·0692	
XII	—	0·0690	—	0·0960	
Lumbar—					
I { Upper ...	0·142	0·0860	0·0871	0·1146	0·1171
{ Middle...	0·268	0·0845		0·1118	
{ Lower ...	0·608	0·0907		0·1249	
II { Upper ...	0·846	0·1029	0·1016	0·1431	0·1491
{ Middle...	1·058	0·1039		0·1522	
{ Lower ...	1·302	0·0980		0·1522	
III { Upper ...	1·558	0·0934	0·0908	0·1821	0·1913
{ Middle...	1·681	0·0922		0·1911	
{ Lower ...	1·918	0·0869		0·2007	
IV { Upper ...	2·064	0·0826	0·0864	0·2388	0·2601
{ Middle...	2·244	0·0905		0·2686	
{ Lower ...	2·484	0·0861		0·2728	
V { Upper ...	2·608	0·0874	0·0984	0·2792	0·2975
{ Middle...	2·794	0·0992		0·3005	
{ Lower ...	2·944	0·1085		0·3127	
VI { Upper ...	3·154	0·1202	0·1267	0·3182	0·3058
{ Middle...	3·205	0·1209		0·3039	
{ Lower ...	3·328	0·1391		0·2952	
VII { Upper ...	3·450	0·1608	0·1692	0·2957	0·2870
{ Middle...	3·557	0·1770		0·2826	
{ Lower ...	3·642	0·1700		0·2827	
Sacral—					
I { Upper ...	3·782	0·1839	0·1943	0·2722	0·2706
{ Middle...	3·906	0·2010		0·2678	
{ Lower ...	4·057	0·1980		0·2717	
II { Upper ...	4·197	0·1988	0·1985	0·2707	0·2699
{ Middle...	4·316	0·1927		0·2714	
{ Lower ...	4·509	0·2040		0·2677	
III { Upper ...	4·623	0·1948	0·2107	0·2688	0·2659
{ Middle...	4·723	0·2145		0·2638	
{ Lower ...	4·858	0·2228		0·2653	
IV { Upper ...	4·974	0·2310	0·2336	0·2606	0·2601
{ Middle...	5·138	0·2373		0·2597	
{ Lower ...	5·312	0·2325		0·2602	
Coccygeal—					
I { Upper ...	5·486	0·2565	0·2565	0·2695	0·2705
{ Middle...	5·622	0·2572		0·2720	
{ Lower ...	5·726	0·2559		0·2700	
II { Upper ...	5·847	0·2658	0·2655	0·2467	0·2498
{ Middle...	5·939	0·2656		0·2552	
{ Lower ...	6·058	0·2653		0·2477	
III { Upper ...	6·174	0·2874	0·2821	0·2216	0·2041
{ Middle...	6·278	0·2766		0·1992	
{ Lower ...	6·331	0·2823		0·1914	

The relative importance of the dorsal and the ventral horns of the grey substance to the total area of the cross-section of the cord varies considerably between the first lumbar and the third coccygeal regions. This is shown in Chart XVI.

The calculations were made with the mean figures of each ratio as given in Table XVI. The ratio $\frac{\text{dorsal horns}}{\text{total area of cross-section of cord}}$ in the region of each nerve is divided by 0.0871, the value of the ratio in the first lumbar region, and similarly the ratios $\frac{\text{ventral horns}}{\text{total area of cross-section of cord}}$ are each divided by 0.1171, the value of that ratio for the first lumbar region.

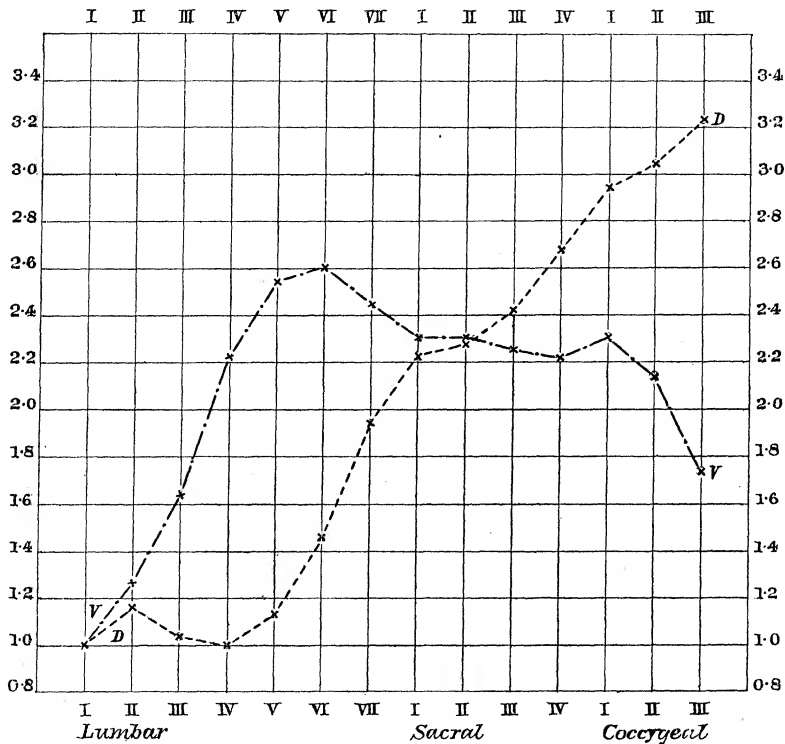


CHART XVI.—Curves showing the Relative Values of the Ratios—

$$\frac{\text{Dorsal Horns}}{\text{Area of Cross-section of Cord}}, \quad \frac{\text{Ventral Horns}}{\text{Area of Cross-section of Cord}}.$$

(D, broken line and cross). (V, line, dot, and cross).

(Table XVII.)

The ratio in the first lumbar region (see Table XVI) is in each case taken as unity. The abscissæ denote spinal nerve regions, the ordinates relative value at corresponding regions.

It will be seen that whereas the ratio $\frac{\text{ventral horns (V)}}{\text{total area of cross-section}}$ taken as unity in the first lumbar region increases rapidly to the sixth lumbar, it decreases at the first sacral, remains constant at the second, falls slightly from this to the fourth sacral, and while rising again in the first coccygeal region, subsequently falls rapidly to the third coccygeal.

On the other hand, the value of the ratio $\frac{\text{dorsal horns (D)}}{\text{total area of cross-section}}$ taken as unity in the first lumbar region increases slightly in the second lumbar, but falls and has practically the same value in the third and fourth lumbar regions as in the first. It then increases rapidly from the fifth lumbar region to the end of the cord.

In regarding the curves together it will be observed that the two ratios V and D, bear roughly the same proportion to each other in the second sacral region that they do in the first lumbar.

A further noteworthy point is that while the dorsal and ventral horns each constitute, relatively, a much larger portion of the total area of the cross-section of the cord in the third coccygeal than in the first lumbar region, the increase is much more important in the case of the dorsal horns (D).

Table XVII.—Relative Values of the Ratios $\frac{\text{Dorsal Horns}}{\text{Area of Cross-section of Cord}}$ and $\frac{\text{Ventral Horns}}{\text{Area of Cross-section of Cord}}$. The ratio in the I Lumbar region (*vide* Table XVI) is in each case taken as unity (Chart XVI).

Region of cord.	Dorsal horns.	Ventral horns.
Lumbar—		
I	1·0	1·0
II	1·17	1·27
III	1·04	1·63
IV	0·99	2·22
V	1·13	2·54
VI	1·46	2·61
VII	1·94	2·45
Sacral—		
I	2·23	2·31
II	2·28	2·30
III	2·42	2·26
IV	2·68	2·22
Coccygeal—		
I	2·95	2·31
II	3·05	2·13
III	3·24	1·74

B5. *Ratio of the Dorsal Columns and of the Ventro-lateral Columns to the Dorsal Horns.*

Table XVIII.—Ratio of the Dorsal Columns and of the Ventro-lateral Columns to the Dorsal Horns taken as Unity in each Cross-section of the Cord (Chart XVII).

Region of cord.	Distance in cm. from uppermost section of I Lumbar region.	Dorsal columns. Dorsal horns.	Mean.	Ventro-lateral columns. Dorsal horns.	Mean.
Dorsal (thoracic) —					
VI	—	3·88			
XII	—	3·31			
Lumbar—					
I { Upper	0·142	2·34	2·53	6·68	6·51
{ Middle	0·268	2·73		6·77	
{ Lower	0·608	2·53		6·08	
II { Upper	0·846	2·20	2·18	5·11	5·17
{ Middle	1·058	2·12		5·03	
{ Lower	1·302	2·22		5·38	
III { Upper	1·558	2·34	2·34	5·40	5·55
{ Middle	1·681	2·31		5·45	
{ Lower	1·918	2·37		5·79	
IV { Upper	2·064	2·40	2·13	5·79	5·42
{ Middle	2·244	1·99		5·07	
{ Lower	2·484	2·00		5·40	
V { Upper	2·608	1·91	1·60	5·28	4·55
{ Middle	2·794	1·51		4·45	
{ Lower	2·944	1·38		3·93	
VI { Upper	3·154	1·12	1·08	3·54	3·41
{ Middle	3·205	1·14		3·62	
{ Lower	3·328	0·383		3·07	
VII { Upper	3·450	0·825	0·776	2·53	2·36
{ Middle	3·557	0·736		2·15	
{ Lower	3·642	0·769		2·41	
Sacral—					
I { Upper	3·782	0·662	0·602	2·28	2·14
{ Middle	3·906	0·582		2·05	
{ Lower	4·057	0·564		2·09	
II { Upper	4·197	0·568	0·595	2·09	2·06
{ Middle	4·316	0·623		2·12	
{ Lower	4·509	0·595		1·99	
III { Upper	4·623	0·598	0·577	2·14	1·92
{ Middle	4·723	0·604		1·90	
{ Lower	4·858	0·595		1·75	
IV { Upper	4·974	0·500	0·498	1·68	1·65
{ Middle	5·138	0·484		1·62	
{ Lower	5·312	0·510		1·65	
Coccygeal—					
I { Upper	5·486	0·391	0·392	1·43	1·43
{ Middle	5·622	0·411		1·41	
{ Lower	5·726	0·376		1·45	
II { Upper	5·847	0·368	0·367	1·46	1·44
{ Middle	5·939	0·376		1·42	
{ Lower	6·058	0·358		1·43	
III { Upper	6·174	0·281	0·280	1·38	1·51
{ Middle	6·278	0·272		1·61	
{ Lower	6·331	0·288		1·54	

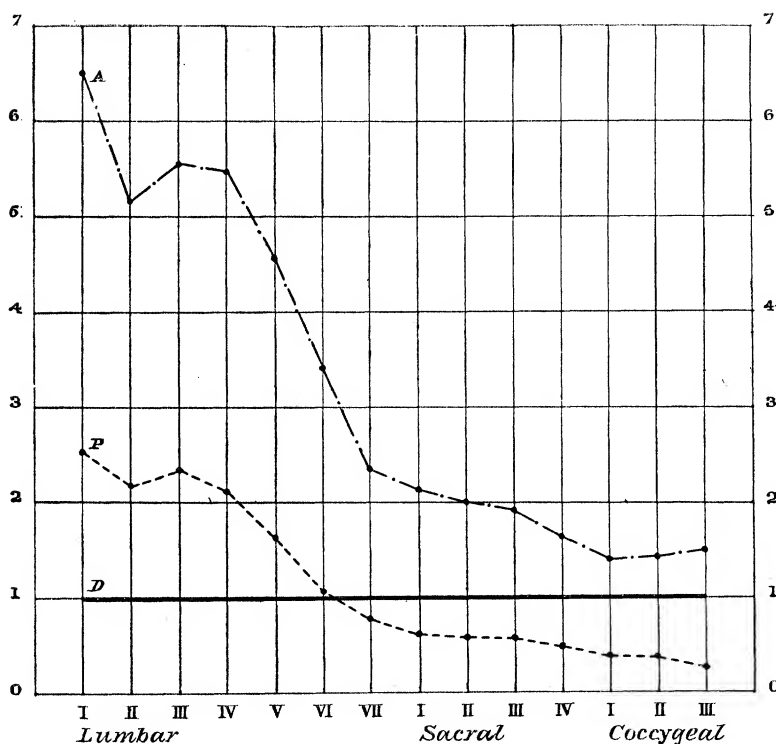


CHART XVII.—Curves showing the Ratio of the Dorsal Columns (P, broken line) and of the Ventro-lateral columns (A, line and dot) to the Dorsal Horns (D).

The dorsal horns taken as unity in each cross-section of the cord. Mean results are plotted (Table XVIII). The abscissæ denote spinal nerve regions, the ordinates ratio at the corresponding regions.

(a) Ratio $\frac{\text{dorsal columns (P)}}{\text{dorsal horns (D)}}$ (Chart XVII, Table XVIII).

The ratio $\frac{\text{dorsal columns (P)}}{\text{dorsal horns (D)}}$ decreases from the first lumbar region to the end of the cord.

The decrease in ratio is very rapid from the first lumbar to the first sacral region. It occurs chiefly in the fifth, sixth, and seventh lumbar regions, and more particularly in the fifth and sixth. The ratio remains very much the same from the first to the third sacral region.

(b) Ratio $\frac{\text{ventro-lateral columns (A)}}{\text{dorsal horns (D)}}$ (Chart XVII, Table XVIII).

The ratio $\frac{\text{ventro-lateral columns (A)}}{\text{dorsal horns (D)}}$ decreases from the first lumbar region to the first coccygeal, and increases slightly in the lower coccygeal regions.

The decrease is slight from the first to the fourth lumbar, but very rapid from the fourth to the seventh lumbar region.

The ratio never becomes as 1 : 1.

B6. *Ratio of the Dorsal Columns and of the Ventro-lateral Columns to the Ventral Horns.*

Table XIX.—Ratio of the Dorsal Columns and of the Ventro-lateral Columns to the Ventral Horns taken as Unity in each Cross-section of the Cord (Chart XVIII).

Region of cord.	Distance in cm. from uppermost section of I Lumbar region.	Dorsal columns. Ventral horns.	Mean.	Ventro-lateral columns. Ventral horns.	Mean.
Dorsal (thoracic)—					
VI	—	—	—	9·27	
XII	—	—	—	6·31	
Lumbar—					
I { Upper	0·142	1·93	1·93	5·01	4·85
{ Middle	0·268	2·05		5·12	
{ Lower	0·608	1·84		4·42	
II { Upper	0·846	1·58	1·48	3·67	3·52
{ Middle	1·058	1·45		3·43	
{ Lower	1·302	1·43		3·47	
III { Upper	1·558	1·20	1·11	2·77	2·63
{ Middle	1·681	1·12		2·63	
{ Lower	1·918	1·03		2·51	
IV { Upper	2·064	0·829	0·709	2·00	1·81
{ Middle	2·244	0·668		1·71	
{ Lower	2·484	0·632		1·76	
V { Upper	2·608	0·599	0·571	1·65	1·50
{ Middle	2·794	0·512		1·47	
{ Lower	2·944	0·604		1·37	
VI { Upper	3·154	0·422	0·444	1·34	1·41
{ Middle	3·205	0·453		1·44	
{ Lower	3·328	0·458		1·45	
VII { Upper	3·450	0·448	0·457	1·37	1·42
{ Middle	3·557	0·463		1·43	
{ Lower	3·642	0·461		1·46	
Sacral—					
I { Upper	3·782	0·447	0·431	1·54	1·53
{ Middle	3·906	0·437		1·54	
{ Lower	4·057	0·411		1·52	
II { Upper	4·197	0·417	0·437	1·53	1·52
{ Middle	4·316	0·442		1·52	
{ Lower	4·509	0·453		1·52	
III { Upper	4·623	0·434	0·449	1·55	1·50
{ Middle	4·723	0·468		1·47	
{ Lower	4·858	0·445		1·47	
IV { Upper	4·974	0·443	0·447	1·49	1·48
{ Middle	5·138	0·442		1·48	
{ Lower	5·312	0·456		1·48	
Coccygeal—					
I { Upper	5·486	0·372	0·373	1·36	1·35
{ Middle	5·622	0·392		1·33	
{ Lower	5·726	0·356		1·37	
II { Upper	5·847	0·397	0·390	1·56	1·53
{ Middle	5·939	0·392		1·48	
{ Lower	6·058	0·383		1·55	
III { Upper	6·174	0·362	0·388	1·78	2·10
{ Middle	6·278	0·378		2·23	
{ Lower	6·331	0·425		2·28	

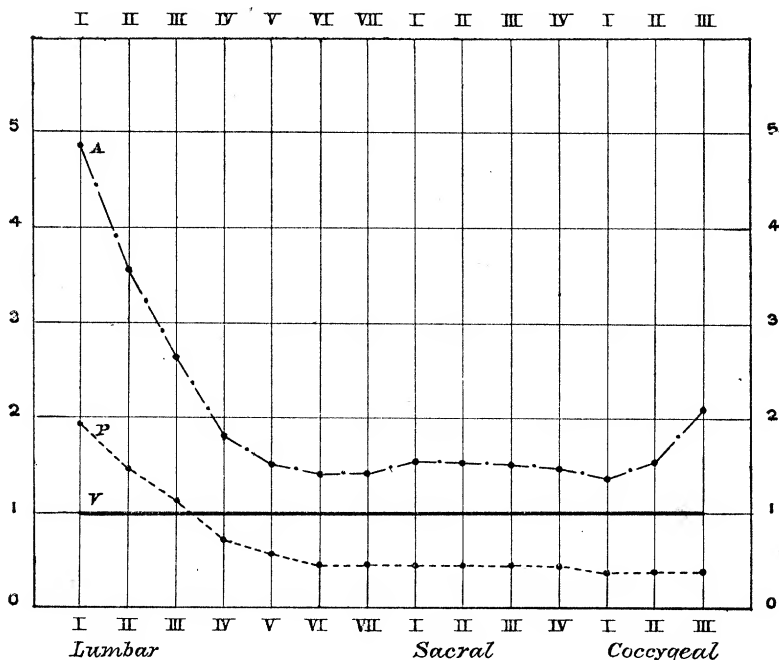


CHART XVIII.—Curves showing the Ratio of the Dorsal Columns (P, broken line) and of the Ventro-lateral Columns (A, line and dot) to the Ventral Horns (V).

The ventral horns taken as unity in each cross-section of the cord. Mean results are plotted (Table XIX). The abscissæ denote spinal nerve regions, the ordinates ratio at the corresponding regions.

(a) Ratio $\frac{\text{dorsal columns (P)}}{\text{ventral horns (V)}}$ (Chart XVIII, Table XIX).

The ratio $\frac{\text{dorsal columns (P)}}{\text{ventral horns (V)}}$ decreases from the first to the sixth lumbar region, the decrease being rapid to the fourth. It remains nearly the same from the sixth lumbar to the fourth sacral region, decreases slightly in the first coccygeal region and varies very little in the second and third.

(b) Ratio $\frac{\text{ventro-lateral columns (A)}}{\text{ventral horns (V)}}$ (Chart XVIII, Table XIX).

The ratio $\frac{\text{ventro-lateral columns (A)}}{\text{ventral horns (V)}}$ decreases rapidly from the first to the sixth lumbar region. The decrease is very marked in the second, third, and fourth, but it is less in the third than in the second, and is again less in the fourth than in the third. The ratio increases very slightly from the sixth lumbar to the first sacral region and remains approximately the same

throughout the regions of the sacral nerves. A slight decrease in the first coccygeal is followed by an increase in the second and third coccygeal regions, the increase being marked in the third.

B7. Relative Increase and Decrease in the Section Area of the Cord and of each of its Component Parts.

A general idea of the relative increase and decrease in the section area of the cord and of its component parts is to be obtained from the following table (XX) and Chart XIX.

The section area of each constituent of the cord at the particular region in which it reaches a maximum value is taken as 100. For the cord as a whole, and for the white substance and its component parts—the dorsal and the ventro-lateral columns—this region is the fourth lumbar; for the grey substance and its component parts—the dorsal and the ventral horns—the fifth lumbar.

The mean figures obtained from the three sections taken in each region were employed (Table XX) in drawing the chart:—

Table XX.—The Section Area of the Cord and of each of its Component Parts at its Maximum Value is taken as 100. The Table gives the mean percentage values of the cross-section of the cord and of each of its component parts in the region of each spinal nerve (Chart XIX).

Region of cord.	Cross-section of cord.	Grey substance.	Dorsal horns.	Ventral horns.	White substance.	Dorsal columns.	Ventro-lateral columns.
Lumbar—							
I	64	34	56	26	80	80	78
II	71	46	73	37	83	87	80
III	76	55	69	51	85	88	82
IV	100	87	84	88	100	100	100
V	94	100	100	100	89	82	90
VI	73	82	92	78	64	54	67
VII	53	63	90	53	45	38	46
Sacral—							
I	39	47	76	37	32	25	35
II	29	35	58	27	24	19	26
III	22	27	45	20	18	14	19
IV	17	21	39	15	13	11	14
Coccygeal—							
I	12	17	31	11	9	7	10
II	7	9	18	6	5	4	5
III	3	4	10	2	3	1	3

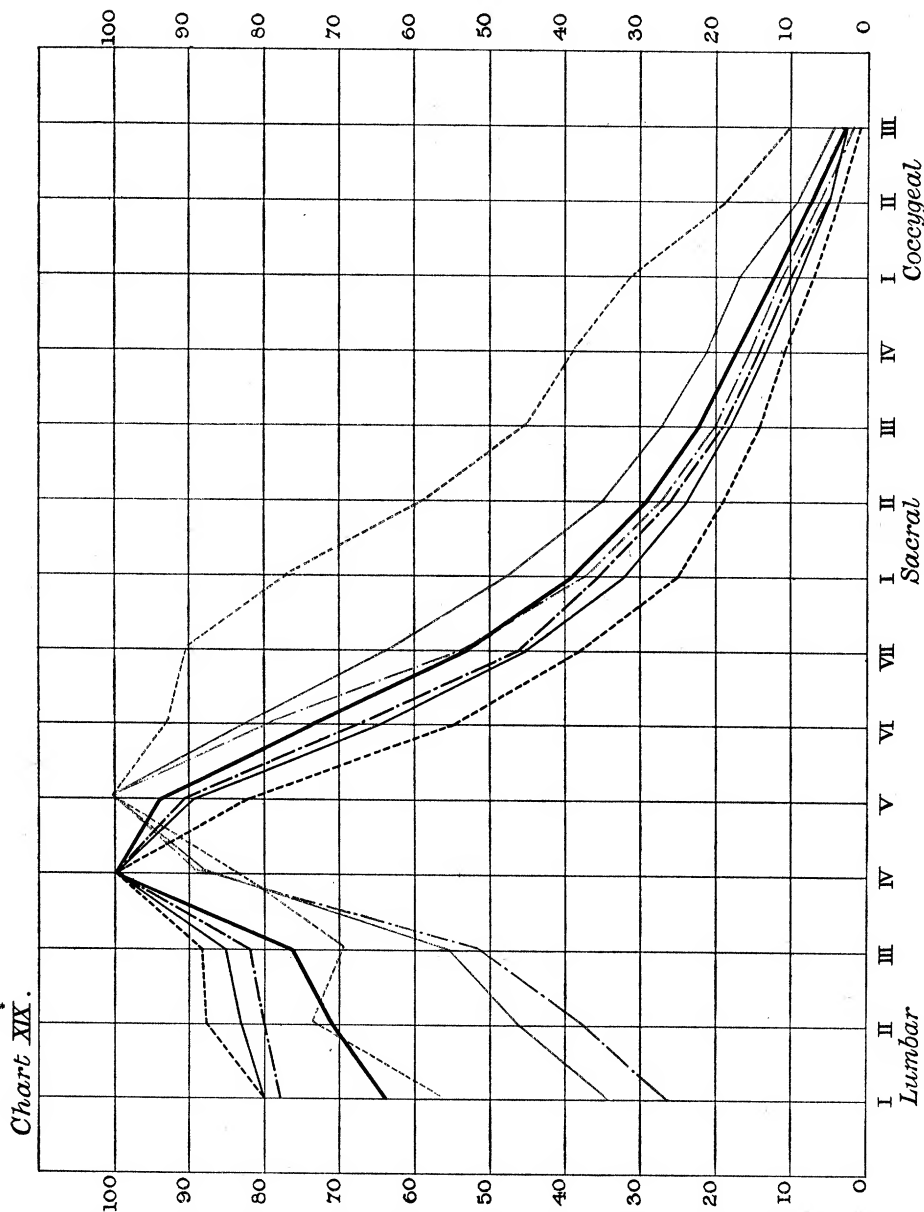


CHART XIX.—Curves showing the Relative Increase and Decrease in the Cross-sectional Area of the Cord, of the Grey and the White Substances and of their Component Parts (Table XX).

The section area at its maximum value is in each case taken as 100. The abscissæ denote spinal nerve region, the ordinates percentage value at corresponding region.

Area of cross-section of cord	Heavy black line.
Section area of grey substance	Red continuous line.
" dorsal horns	Red broken line.
" ventral horns.....	Red line and dot.
" white substance.....	Thin black continuous line.
" dorsal white columns	Thin black broken line.
" ventro-lateral white columns	Thin black line and dot.

Thus it is seen that:—

(1) In sectional area, both the white substance as a whole, and the ventro-lateral and dorsal columns, increase with the cord from the first to the fourth lumbar region, and decrease together with the cord from the fourth lumbar to the third coccygeal region.

(2) The increase in the white substance is relatively less than that in the cord, whereas the decrease is relatively greater.

(3) Of the white substance, both the ventro-lateral and dorsal columns increase relatively less than the cord, and decrease relatively more to the second coccygeal region. From this region the decrease in the ventro-lateral columns is relatively less than that in the cord, though the decrease in the dorsal columns continues to be relatively greater.

(4) The ventro-lateral columns increase relatively rather more than the dorsal columns, and decrease relatively less.

(5) The decrease in the dorsal columns is relatively greater than the decrease in any other component part of the cord.

(6) In sectional area, both the grey substance as a whole, and the ventral and dorsal horns, increase with the cord and white substance, from the first to the fourth lumbar region, and *continue to increase to the fifth lumbar region*, whilst the cord and white substance are decreasing. The grey substance and the ventral and dorsal horns decrease with the cord and white substance from the fifth lumbar to the third coccygeal region.

(7) The increase of the grey substance is relatively much greater than the increase of the cord, and is still greater than the increase in the white substance. The decrease is relatively less than that of the cord, and much less than that of the white substance and its component parts.

(8) Of the grey substance, both the ventral and dorsal horns increase relatively more than the cord, the white substance and its component parts.

(9) The increase in the “ventral horns” is relatively much greater than that in any other component part of the cord, and is considerably greater than the increase in the “dorsal” horns.

(10) The ventral horns decrease in much the same proportion as the cord (or relatively rather less to the seventh lumbar region and subsequently rather more). They decrease relatively less than the white substance and its component parts, to the second coccygeal region, where the decrease becomes relatively greater than the decrease in the ventro-lateral columns.

(11) The decrease of the “dorsal horns” is relatively less than that of the cord and of any other part of the same.

The rate of increase or decrease of the section area of the cord, of the grey

and the white substances and of their component parts, between the region of one spinal nerve and that of the next, is shown in the following chart (XX). The calculations were made with the mean sectional area figures as given in Tables I to V, and XII, XIII.

Taking the total area of the cross-sections of the cord as the example (Chart XX, heavy black line, S), the method employed was as follows: The mean sectional area of the first lumbar region was taken as unity. The value of the second point of the curve was obtained by dividing the mean sectional area of the second lumbar region by that of the first lumbar; similarly the value of the third point of the curve was obtained by dividing the mean sectional area of the third lumbar region by the mean sectional area of the second lumbar, and so on throughout the remaining regions of the cord.

To render comparison easy, the curves are arranged in three separate groups in the same chart. The rate of increase and decrease in the section area of the cord, the grey and the white substance is indicated by the curves in Group S, that of the white substance and its component parts, the ventro-lateral and the dorsal columns, in Group Z, and that of the grey substance and the ventral and dorsal horns in Group B.

All the curves are comparable one with another.

Table XXI.—Rate of Increase and Decrease in the Sectional Area of the Cord and of each of its Component Parts. The mean sectional area of the first lumbar region is in each case taken as unity (Chart XX).

Region of cord.	Cross-section of the cord.	Grey substance.	Dorsal horns.	Ventral horns.	White substance.	Dorsal columns.	Ventro-lateral columns.
§							
Lumbar—							
I	1·0	1·0	1·0	1·0	1·0	1·0	1·0
II	1·1	1·4	1·3	1·4	1·1	1·1	1·0
III	1·1	1·2	1·0	1·4	1·0	1·0	1·0
IV	1·3	1·6	1·2	1·7	1·2	1·1	1·2
V	0·9	1·1	1·1	1·1	0·9	0·8	0·9
VI	0·8	0·8	1·0	0·8	0·7	0·7	0·7
VII	0·7	0·8	1·0	0·7	0·7	0·7	0·7
Sacral—							
I	0·7	0·7	0·8	0·7	0·7	0·6	0·7
II	0·8	0·8	0·8	0·8	0·7	0·8	0·7
III	0·7	0·8	0·8	0·7	0·7	0·8	0·7
IV	0·8	0·8	0·9	0·8	0·7	0·8	0·7
Coccygeal—							
I	0·7	0·8	0·8	0·7	0·7	0·6	0·7
II	0·5	0·5	0·6	0·5	0·6	0·5	0·6
III	0·5	0·5	0·5	0·4	0·5	0·4	0·6

Thus the total area of the cord in the second lumbar is 1·1 times its area in the first, from thence to the third lumbar the increase is at the same rate

Chart XX.

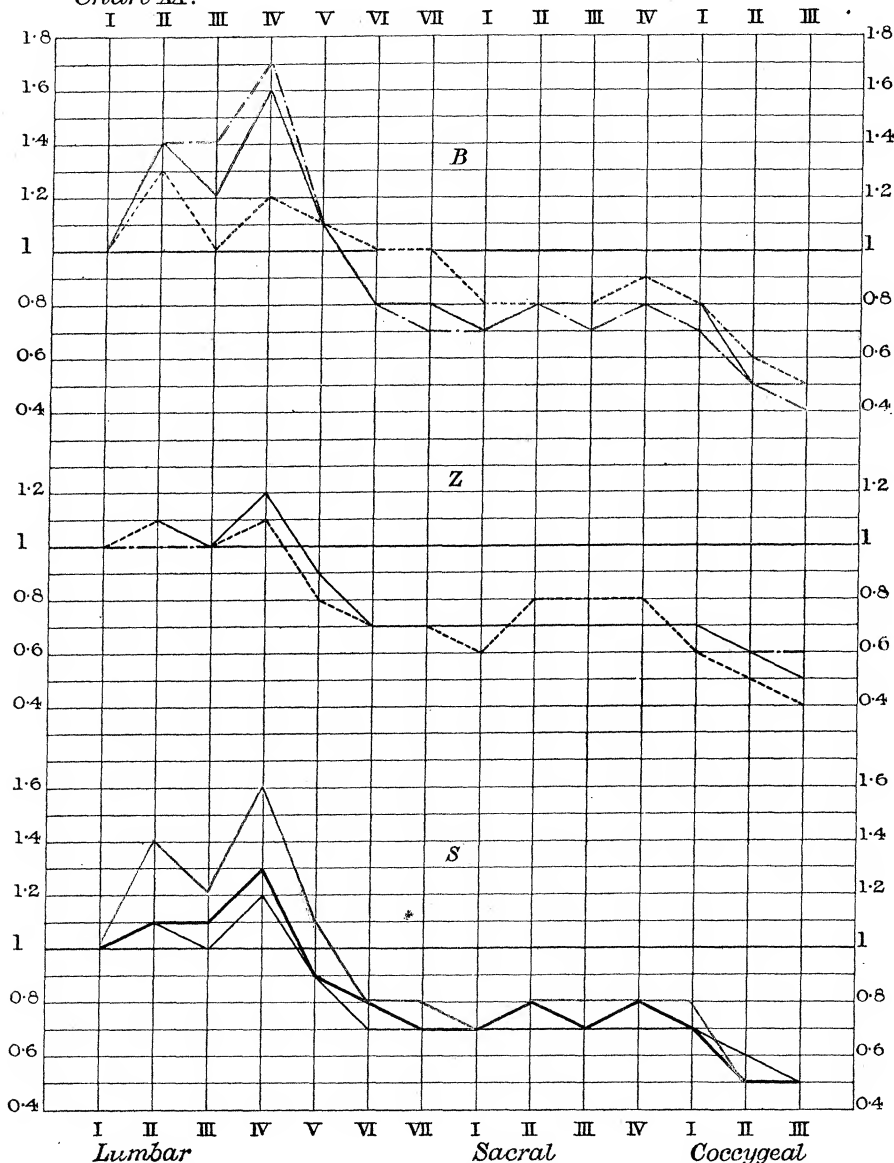


CHART XX.—Curves showing the Rate of Increase or Decrease of the Section Areas of the Cord, the Grey and the White Substances, and their Component Parts (Table XXI).

The mean sectional area of the first lumbar region is in each case taken as unity. The abscissæ denote spinal nerve regions, the ordinates rate of increase or decrease.

Group S.—Cross-section of cord.....	Heavy black line.
Total grey substance	Red line.
Total white substance	Thin black line.
Group Z.—Total white substance	Black continuous line.
Dorsal white columns	Black interrupted line.
Ventro-lateral white columns ...	Black line and dot.
Group B.—Total grey substance.....	Red continuous line.
Dorsal horns	Red interrupted line.
Ventral horns.....	Red line and dot.

the area at the third lumbar being 1.1 times the area at the second. At the fourth lumbar the increase is more rapid, namely, 1.3, but at the fifth lumbar the section area is only 0.9 that at the fourth lumbar, and so on.

Summary.

From the examination of the cross-sections of the lumbo-sacral-coccygeal cord of the Macaque monkey (*Macacus sinicus*), it is seen that:—

(1) The maximum section area of the cord, of the white substance as a whole, as well as of the dorsal and the ventro-lateral columns is found in the fourth lumbar region.

(2) The maximum section area of the grey substance as a whole, and of the dorsal and the ventral horns, is found in the fifth lumbar region.

(3) Reckoning the cross-sectional area of the cord as 100, the maximum percentage of the white substance as a whole, and of the dorsal and the ventro-lateral columns, is found in the first lumbar region.

(4) The maximum percentage of the grey substance is reached in the first coccygeal region.

(5) Reckoning the total area of the grey substance in each cross-section of the cord as 100, the maximum percentage of the dorsal horns is found in the third coccygeal region, and that of the ventral horns in the fifth lumbar region.

For the furtherance of this research on the spinal cord of the Macaque monkey, a series of drawings has been made of the minute structure of the grey substance, for the purpose of determining the arrangement of the cell groups at the different levels of the cord.

It has been thought advisable to deal with this portion of the research in a separate paper.

In conclusion, I desire to thank Professor Gotch for having allowed me to carry out this research in the Physiological Laboratory, Oxford, and for his kind advice. I also wish to express my sincere thanks to many others who have assisted and encouraged me, especially to Dr. G. Mann, at whose suggestion the work was undertaken, for his guidance and kind help; to Dr. G. J. Burch, for his ready assistance in many ways, and to Professor C. S. Sherrington (Liverpool), for his valuable criticism and suggestions.

Chart XXI.

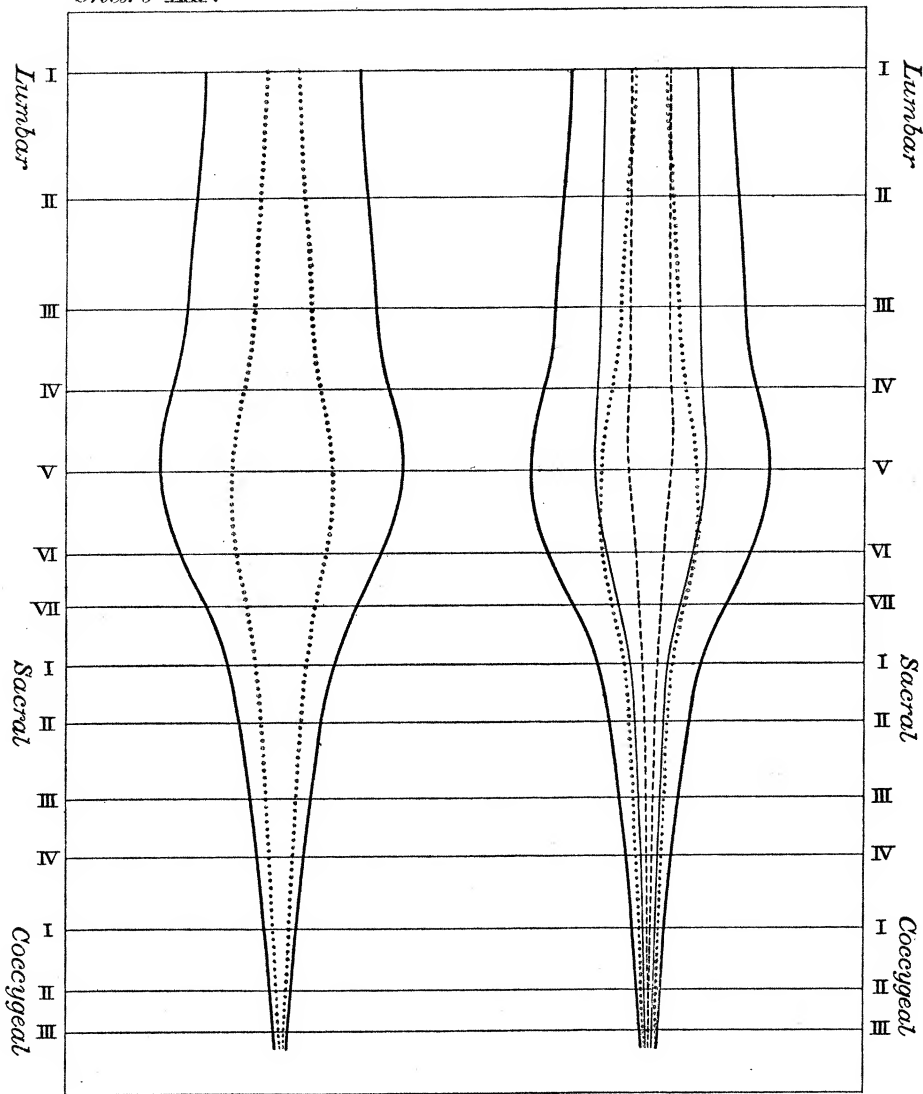


Fig. 1.

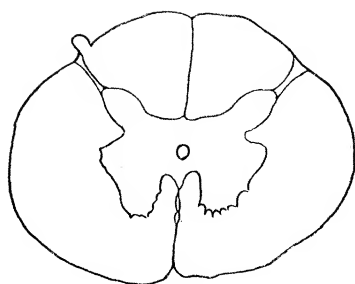
Fig. 2.

CHART XXI.

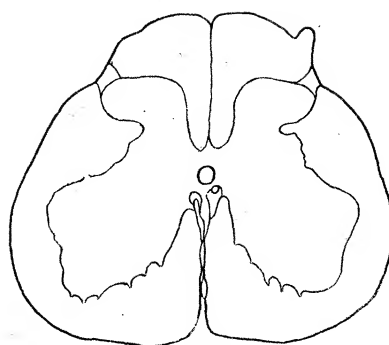
CL. DIAGRAM.—General Configuration of the Lumbo-sacral-coccygeal Cord in Sectional Area.

The figures (1, 2) are drawn to scale. The actual length of the cord is increased two-and-a-half times, and the sectional area to twice its actual value. Mean sectional area figures are employed. It must be remembered that the *sectional area* is plotted in one dimension, and that the *width* of the cord from side to side is not represented* (see p. 144).

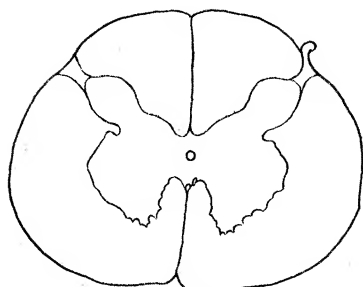
Fig. 1.—Area of the cross-section of the cord Heavy black line.
 Section area of grey substance Red dotted line.
 „ 2.—Area of the cross-section of the cord Heavy black line.
 Section area of the grey substance..... Red dotted line.
 „ „ dorsal white columns Thin black broken line.
 „ „ ventro-lateral white columns... Thin black continuous line.



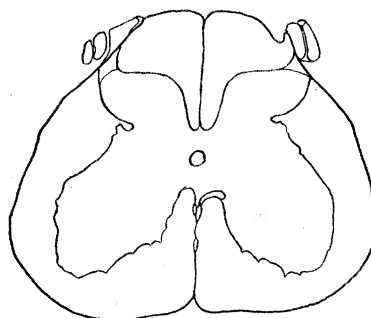
I L.



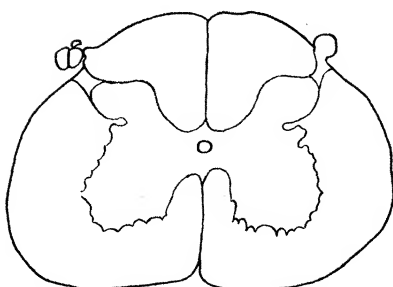
V L.



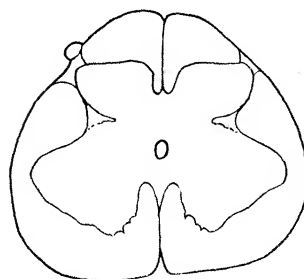
II L.



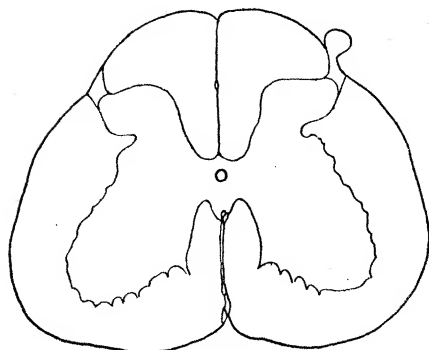
VI L.



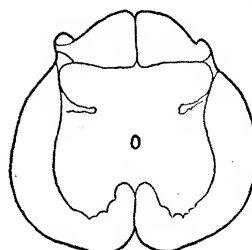
III L.



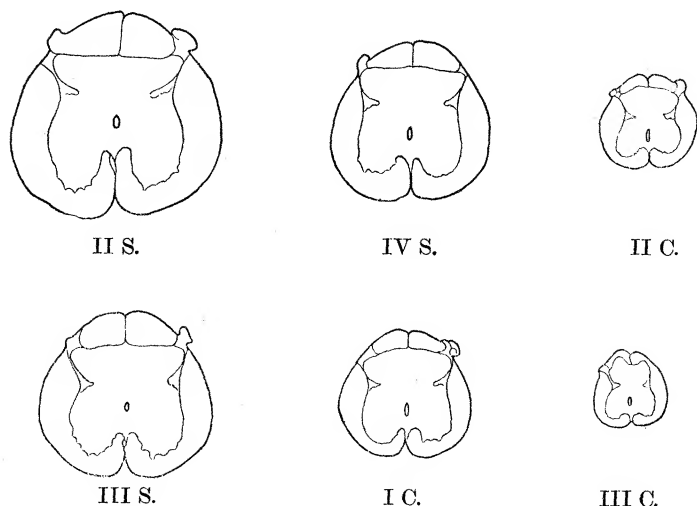
VII L.



IV L.



I S.



C2.—Outline Drawings of the Cross-section of the Cord in the Region of each Spinal Nerve. Magnification, 10 diameters.

	Distance in cm. from uppermost section of I lumbar region.		Distance in cm. from uppermost section of I lumbar region.
I Lumbar (upper)	0·142	I Sacral (upper)	3·792
II Lumbar (middle)	1·068	II Sacral (middle)	4·293
III Lumbar (middle)	1·710	III Sacral (middle)	4·768
IV Lumbar (lower)	2·338	IV Sacral (upper)	5·054
V Lumbar (lower)	2·998	I Coccygeal (middle) ...	5·644
VI Lumbar (middle)	3·191	II Coccygeal (middle) ...	5·976
VII Lumbar (upper)	3·518	III Coccygeal (upper)	6·193

Footnote to p. 142.

* The subject of cubic volume has not been entered into, but a passing reference is made to the relatively small volume of grey substance in the sixth lumbar region of the present monkey. In a region of such great physiological importance this is a matter of surprise, and may be due to error; but against this view is the fact that, on examining the cord of another Macaque monkey, the volume of the grey substance in the fifth lumbar was again found to be greater than that of the sixth or seventh, though the difference between the fifth and sixth was not so marked as in the present instance. A further examination of several Macaque cords would be necessary to determine this point.

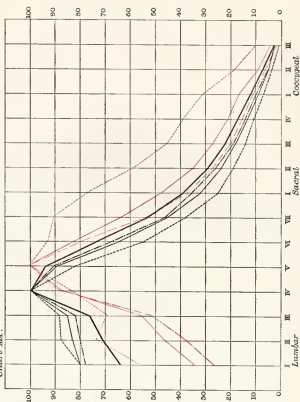


CHART XIX.—Curves showing the Relative Increase and Decrease in the Cross-sectional Area of the Cord, of the Grey and the White Substances and of their Component Parts (Table XX).

The section area at its maximum value is in each case taken as 100. The abscissæ denote spinal nerve region, the ordinates percentage value at corresponding region.

Area of cross-section of cord	Heavy black line.
Section area of grey substance	Red continuous line.
" dorsal horns	Red broken line.
" ventral horns	Red line and dot.
" white substance.....	Thin black continuous line.
" dorsal white columns	Thin black broken line.
" ventro-lateral white columns	Thin black line and dot.

Chart XX.

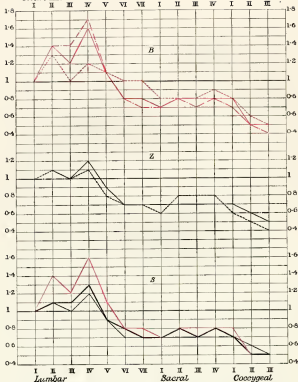


CHART XX.—Curves showing the Rate of Increase or Decrease of the Section Areas of the Cord, the Grey and the White Substances, and their Component Parts (Table XXI).

The mean sectional area of the first lumbar region is in each case taken as unity. The abscissæ denote spinal nerve regions, the ordinates rate of increase or decrease.

Group S.—Cross-section of cord.....	Heavy black line.
Total grey substance	Red line.
Total white substance	Thin black line.
Group Z.—Total white substance	Black continuous line.
Dorsal white columns	Black interrupted line.
Ventro-lateral white columns...	Black line and dot.
Group B.—Total grey substance.....	Red continuous line.
Dorsal horns	Red interrupted line.
Ventral horns.....	Red line and dot.

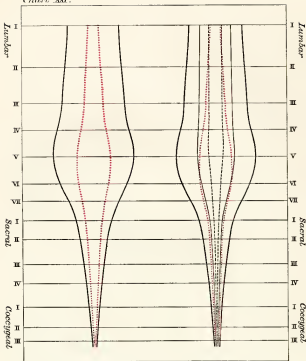


Fig. 1.

Fig. 2.

CHART XXI.

CL. DIAGRAM.—General Configuration of the Lumbo-sacro-coccygeal Cord in Sectional Area.

The figures (1, 2) are drawn to scale. The actual length of the cord is increased two-and-a-half times, and the sectional area to twice its actual value. Mean sectional area figures are employed. It must be remembered that the sectional area is plotted in one dimension, and that the width of the cord from side to side is not represented* (see p. 144).

Fig. 1.—Area of the cross-section of the cord	Heavy black line.
Section area of grey substance	Red dotted line.
" 2.—Area of the cross-section of the cord	Heavy black line.
Section area of the grey substance	Red dotted line.
" " dorsal white columns	Thin black broken line.
" " ventro-lateral white columns...	Thin black continuous line.